DOCUMENTED BRIEFING

RAND

Joint Operations Superiority in the 21st Century

Analytic Support to the 1998 Defense Science Board

John Matsumura, Randall Steeb, Ernest Isensee, Thomas Herbert, Scot Eisenhard, John Gordon

Arroyo Center
National Defense Research Institute

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Prepared for the
United States Army
Office of the Secretary of Defense

Arroyo Center
National Defense Research Institute

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PREFACE

This document describes RAND research that supported the 1998 Defense Science Board (DSB) Summer Study on *Joint Operations Superiority in the 21st Century: Integrating Capabilities Underwriting Joint Vision 2010.* More specifically, this work involved assessing several different Joint force concepts that could be applied to resolve a notional high-intensity, quick-reaction scenario around the 2010–2015 time period. RAND supported the DSB through both exploratory analysis and high-resolution simulation-based analysis; this document only covers the high-resolution work.

Research was conducted over a four-month period within two of RAND's federally funded research and development centers (FFRDCs), the Arroyo Center and the National Defense Research Institute (NDRI). More specifically, RAND Arroyo Center research was conducted within the Force Development and Technology Program; NDRI research was conducted within the Acquisition and Technology Policy Center. The work was sponsored, respectively, by the Army's Office of the Deputy Chief of Staff for Operations and Plans and the Office of the Undersecretary of Defense for Acquisition and Technology. The Arroyo Center is sponsored by the United States Army, and NDRI is sponsored by the Office of the Secretary of Defense, the Joint Staff, the unified commands, and the defense agencies.

Any questions regarding the content of this research should be directed to the authors.

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SUMMARY

MOTIVATION FOR RESEARCH

Although the defense community has come to endorse "jointness" in military operations, views differ greatly on what operations should look like in the future. *Joint Vision (JV) 2010* provides basic ideas on how people and technologies might best be used to shape Joint warfare in the future, but it is a vision document that is intended to serve as a conceptual template, not a blueprint. The Defense Science Board (DSB) was asked to help move things forward by focusing "on how new capabilities, operational concepts, and different force characteristics can be developed and integrated to underwrite *Joint Vision 2010*."[1]

This report describes part of RAND's analytical support of the DSB summer study, notably simulation experiments to help explore and assess Joint operational concepts. It builds on related work done by the authors for a previous DSB effort, Tactics and Technology for 21st Century Military Superiority.[2] In this year's effort, we not only drew on outcomes of such previous DSB studies, but also included new discussions with warfighters and planners in the Joint warfare community, and interactions with DSB members, to define a range of operational concepts for the future. The strengths and weaknesses of these concepts were explored using man-in-the-loop, high-resolution, stochastic constructive simulation in the context of a single basic scenario with a number of variations. Our intention in this detailed work was to: (1) provide insights and inputs for a broader, exploratory RAND analysis for the DSB, (2) increase dialogue among conceptualizers, users, and developers, and (3) suggest ideas that would indeed help the DSB take *JV 2010* to the next step. An additional objective made clear by the summer study's leadership from the outset was to illustrate the kinds of analysis needed to assess new concepts. That

[1]From a letter attachment, "Terms of Reference—Defense Science Board 1998 Summer Study Task Force on Joint Operations Superiority in the 21st Century: Integrating Capabilities Underwriting Joint Vision 2010."

[2]See J. Matsumura, R. Steeb, T. Herbert, M. Lees, S. Eisenhard, and A. Stich, *Tactics and Technology for 21st Century Military Superiority: Analytic Support to the Defense Science Board*, Santa Monica, CA: RAND, DB-198-A, 1997.

is, the leadership saw the current effort as the beginning of what should be sustained community analytical efforts.

FOUR JOINT CONCEPTS EXPLORED

We examined four very different Joint operational concepts in a notional 2010–2015 scenario designed to highlight issues associated with phrases such as "information dominance" and "dominant maneuver, " and to do so for operational circumstances different from those heavily studied in recent years. The scenario involved early neutralization/disruption of a highly mobile, elite enemy unit located behind enemy lines with plausible quick-reaction U.S. forces. That is, the scenario postulated almost immediate "offensive" operations as part of initial U.S. efforts to help the defending ally stop and defeat the invader. All four concepts involved the aggressive use of long-range attack weapons represented by aircraft delivering standoff weapons such as Joint Standoff Weapon (JSOW) and Navy and Army versions of the Tactical Missile System (TACMS), which were equipped with advanced submunitions. However, the four Joint concepts differed markedly in the level of operational and tactical maneuver with ground forces, and how those forces would be used. All four concepts were examined with a range of assumptions about reconnaissance, surveillance, and target acquisition (RSTA) and command and control (C2).

Suppression of enemy air defenses (SEAD) was seen to be a critical precursor to all concepts, since we assumed that an advanced future threat would respond to U.S. air superiority with fully integrated air defenses. We did not directly model or simulate this part of the concepts; we assumed that enough SEAD capability would be in place to gain access to the deep enemy battlespace (e.g., successfully clearing an airspace corridor to permit short-range standoff weapons to be delivered and to bring in transport aircraft carrying ground forces).[3]

The first concept explored using long-range, standoff attack alone to neutralize the deep mobile enemy unit. The second concept built on the standoff capability by adding a conventionally organized airborne ground

[3]Since all concepts involve rapid reaction to the invasion in a matter of days, it was deemed unlikely that the entire enemy air defense network could be neutralized. Instead, available SEAD assets were focused strictly on clearing ingress and egress routes and selected areas of operation.

force with updated sensors, C2, and weapons. The third concept used a more agile and more dispersed ground force (sometimes referred to as the enhanced medium-weight strike force) instead of the conventional airborne force.[4] The fourth concept used the same force composition as the third but applied it differently, using the force to attack the relatively "soft" parts of the enemy force rather than the lethal combat units. One measure of effectiveness—kills of enemy and losses of the ground force—is shown in Figure S.1 for the four different concepts (labeled cases 1–4). Each pair of bars in the chart shows, respectively, losses of Red and Blue forces. The last pair indicates a representative "equivalent" effect from disruption.

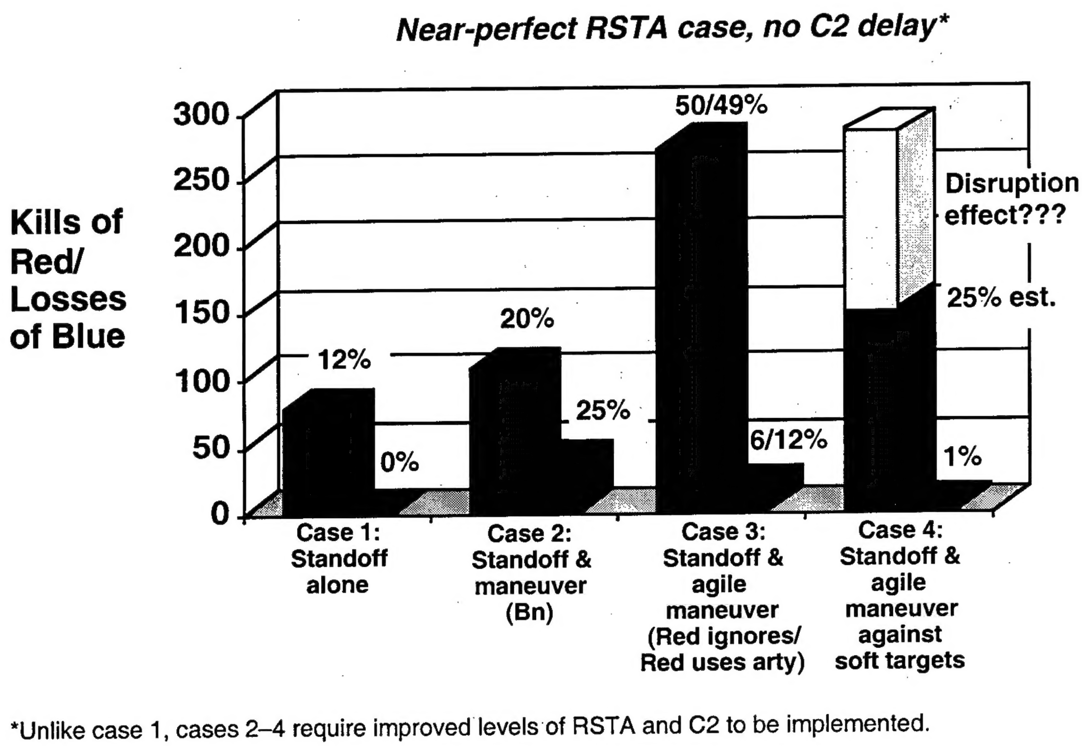

Figure S.1—Increasing Levels of Maneuver Provided Ability to Accomplish Mission: Different Applications Impact Both Survivability and Lethality

[4]This concept is one that has many similarities to the USMC's Hunter Warrior, DARPA's Small Unit Operations, and TRADOC's Army After Next Battle Unit and Mobile Strike in that it is a rapidly deployable future force designed around a family of lightweight and agile ground forces.

RESEARCH FINDINGS

In examining the alternative operational concepts we also addressed three key questions: (1) To what extent can information superiority, via improved RSTA and C2 capabilities and decisionmaking, enhance future joint operations? (2) How should we think about the relationship between maneuver and firepower, for different RSTA and C2 capabilities? and (3) What are the major factors that affect force effectiveness? Our conclusions follow.

Improved Decisionmaking Can Enhance Future Joint Operations

Improved decisionmaking made possible by new RSTA and C2 capabilities was seen to be the key enabler allowing a rapid Joint response (e.g., force insertion and force application) against the rear area of an enemy advance, without the requisite "conventional" build-up time.[5] Vulnerable and lucrative areas on the battlefield, which might constitute the enemy's center of gravity, could be targeted for attack. Similarly, the most dangerous and lethal part of the enemy's battlespace could be identified and, in some cases, avoided during force deployment.

However, the Joint task force (JTF) commander's ability to affect the battlespace ultimately was not governed by RSTA and C2 capabilities alone. Even when we assumed a near-perfect (complete, accurate, fused, and timely) RSTA and C2 capability, which greatly improved the planning process, we found that the ability to execute the battle plan fell short in a number of other areas—reinforcing the notion that RSTA and C2 capabilities are only one piece of a larger system. More specifically:

- Enemy air defenses, even if located with advanced RSTA, must be neutralized. Since these systems are likely to be mobile (e.g., SA-12) and can outrange most friendly weapon systems, these defenses must

[5]In our assessment of RSTA and C2, we opted for a parametric representation. In modeling RSTA, we used five parameters: comprehensiveness, both in and out of foliage, ability to discriminate, and accuracy and latency. C2 was represented as a time delay. Although other attributes such as false alarm rate and degree of fusion would ideally be included, these were not examined due to time constraints. Also, we did not examine the ability for an enemy force to negate U.S. RSTA and C2 capabilities. Nor did we give the enemy a comparable level of RSTA and C2 that U.S. forces enjoyed. This suggests that our findings, if anything, may err toward the conservative, favoring Blue effectiveness.

be countered or destroyed quickly. In some cases, it may not be feasible within the time-and-space requirements.

- Ability to conduct standoff operations was largely limited by the weapon system. Long time of flights, limited engagement zones (due to foliage), and imperfect munition logic led to relatively low weapon efficiencies.[6]

- Ability to conduct maneuver operations was seen to be largely limited by intratheater mobility capability. Even if RSTA and C2 were able to provide enough intelligence on where the threat systems were concentrated (including the air defense network), cross-FLOT operations might pose unacceptable risk.

In conjunction with SEAD, air superiority, RSTA and C2, improved capabilities in the areas of maneuver, and engagement were seen as necessary to accomplish U.S. objectives in this scenario.

Standoff Engagement and Maneuver Capabilities Complement Each Other

To be able to accomplish early neutralization and otherwise blunt invasions with standoff weapons alone would, of course, be very desirable. Ideally, weapons would be able to: (1) perform well in difficult and complex terrain, (2) be insensitive to weather and obscurants, (3) be able to acquire all target types of importance, discriminating among good, unimportant, dead, and decoy targets, and (4) have very fast times to react (perhaps through loitering platforms) or be capable of being retargeted during flight. More generally, they should be adaptable to the changing conditions of the battlefield, whether these are threat controlled or environmentally dominated.[7] There are of course physical limitations on how many of these ideals can be achieved in the 2015 time frame.

Currently planned, notional long-range weapon systems are not far enough along to fully capitalize on high-end RSTA and C2 capabilities.

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[6]Typically, even with near-perfect RSTA and C2, we saw around 0.3 kills per JSOW (joint standoff weapon) and 0.6 kills per TACMS (tactical missile system). Foliage presented a key problem in this scenario. When foliage was removed, weapon effectiveness increased roughly threefold. Positioning missiles in theater (missiles in a box) to augment standoff fires (e.g., reducing flyout response times) also increased weapon effectiveness substantially.

[7]Ground forces using organic weapons can do most of these at some level already.

From a weapon platform perspective, systems that are physically close to the target and coupled to sensors have opportunities that long-range systems simply do not have. In addition to increased probability of encountering a target, systems that are physically close have a shorter feedback cycle (e.g., time to determine whether the engagement was successful and whether additional munitions need to be applied).

Although long-range firepower caused some attrition, it had clear limitations in our scenario. When terrain and other physical conditions were changed, the amount of attrition improved. *However, there was little ability to actually control the battlefield with this capability alone. As a result, the enemy could change the conditions back to his favor through a variety of countermeasures.*

From a maneuver perspective, RSTA and C2 tended to be dominant factors—unlike with standoff engagement alone, in which the benefit of RSTA and C2 reached a plateau relatively quickly.

- Because the investment and risk of a maneuver-based operation tends to greatly exceed one that involves standoff engagement alone, RSTA and C2 were seen to be premium assets from a different perspective. Knowing where an enemy is located, what he is doing, and where he is going is critical (more so than with standoff engagement), because the consequences of incomplete and/or inaccurate information can take more catastrophic forms.[8]
- Unlike firepower, maneuver provides a means to control the battlespace. In addition to causing shock and efficient selective destruction, it was apparent that many other effects could be achieved (controlling enemy movement, controlling terrain) that were not reasonable expectations with standoff engagement alone.[9]
- If ground force maneuver in the enemy's rear is needed, as in this scenario, one way to decrease risk might be through the use of unmanned or robotic systems. The success of local indirect fires (missile pods) and other unattended ground sensors and unmanned ground and air vehicles in this study and related studies suggests

[8]For example, complete destruction of force due to incomplete or inaccurate information resulting in an inappropriate insertion or extraction.

[9]The use of remotely delivered mines might have provided a means for greater control; however, without overwatch protection such a minefield is susceptible to being breached.

high-potential payoff. Although not studied here, orbiting armed UAVs might yield similar benefits.

The engagement process employing standoff, local indirect, and direct fires should embody the most efficient combination and sequencing of weapons, provided necessary deconfliction levels can be obtained. For example, we found that long-range weapons fired from standoff, which characteristically have large-footprint submunitions, could best be used against large target groups moving predictably and toward open areas. In the close, covered terrain examined here, the opportunities for using these weapons were much more limited than expected. Local indirect fire weapons could help establish the conditions for other direct fire weapons and serve also as a means of more robust and selective attrition. These systems can react to smaller exposure intervals than the long-range systems can. Direct fire systems provide quick cycle times and shock, offering the highest degree of robustness and efficiency. (See Table S.1.) While long-range fires could have been employed in greater numbers, resulting in better overall results, their efficiency would have dropped even farther.

Table S.1

Direct Fire Weapons and Organic Weapons with Updates Were Seen to Be More Efficient (per Munition) Than Long-Range Weapons

Weapon Class	Time-of-Flight (TOF)/ Distance Traveled	Number Weapons Fired/ Number Targets Killed
Direct fire		
LOSAT	2–3 sec./2–4 km	120/95
Organic indirect fire (w/update)		
AEFOG-M	2–3 min./5–20 km	144/99
Organic indirect fire (no update)		
MLRS-Pod (3 subs)	1–2 min./10–40 km	260/65
Long-range standoff fire		
JSOW (2 subs)	10 min./40 km	144/42
TACMS (13 subs)	10 min./150+ km	68/35

Other Scenario Variables Can Govern Outcome

Many countermeasure options are available to the future threat postulated in our scenario. He can disperse his forces, move in unpredictable ways, use deception, employ jammers, launch EMP weapons to neutralize parts

of the battlefield, use active protection systems, activate counter-reconnaissance units, prepare the battlespace, etc. Most of these can have a large impact on a standoff firepower-based capability alone. Maneuver—when feasible—would provide some levels of robustness, allowing some counterconditioning of the battlespace. In addition to threat countermeasures, the more obvious scenario variable is weather. It can degrade U.S. overhead and ground sensor capability, deny use of air power, negate effectiveness of smart munitions, reduce mobility of maneuver forces, and reduce throughput and timeliness of C2, among others. Other less obvious factors include battlefield "friction," fog of war, and systems simply not working as expected. When these happen (and they do, e.g., Mogadishu), "system" robustness will then be the default judge of force effectiveness. Thus, by our analysis, although standoff firepower has clear value, it would be one piece of a larger maneuver-based Joint operation. This maneuver operation can be enhanced with full-dimensional protection (insertion and combat) and focused logistics (for greater deployability and sustainment).

CONCLUSIONS

As the United States moves toward defining and ultimately fulfilling some of the ideas in *JV 2010*, and as more precision engagement capabilities become available, it became apparent in our scenario that standoff capabilities would play a key role. All of the operational concepts we considered involved maximum use of this capability. The critical elements of the technology are in place[10] to carry long-range precision fires well into the future. However, we found that precision engagement by itself has key weaknesses, many of which cannot be overcome in certain situations. Technology may be able to offset or reduce the impact of some of these; however, development time and cost may be nontrivial. More important, some weaknesses/limitations may not be resolvable with new technologies, regardless of cost. Accounting for enemy behavior, precision standoff engagement appears to be easily countermeasureable, specifically in difficult terrain. Although we can envisage some counter-countermeasures (e.g., use of persistant, loitering weapons, update-in-flight of munitions, employment of mines), it is not apparent how effective

[10]However, capabilities to detect, track, and identify dismounted enemy forces and to perform battle damage assessment are not yet in hand, and may be difficult to achieve in this time period.

these will be.[11] Thus, caution and hedging are very desirable. Although there are also risks to and countermeasures against use of small ground force maneuver units of the class we examined, having a mix of long-range fires and such maneuver appears to be quite beneficial from a mission success perspective.

For the ground maneuver capabilities we explored in this work to become viable, some key capabilities would have to be implemented. One major limiting factor was the nature of the ground force itself. Current quick-reaction ground forces (consisting mostly of dismounted infantry) can be deployed quickly, but without adequate maneuver capability, their mission scope is very constrained. More specifically, such forces can defend terrain but can also be bypassed or attacked with few options for response. Adding more maneuverablity/agility to such quick-reaction forces had a clear payoff in our work. A quick-reaction force, equipped with agile maneuverability, could set up ambush points and pursue or attack an enemy that opted to bypass. In the case where the enemy chooses to engage, the quick-reaction force could opt to disengage with its greater agility, and re-engage at a time and place of *its* chosing; this became especially attractive with higher levels of RSTA and C2 capability.

As noted before, aggressive levels of SEAD—or, better, JSEAD—or some other way to counter a range of air defenses would be required to deploy such a ground force.[12] Also, given that tactical agility requires the use of combat vehicles, a viable means for quickly deploying this force would be needed (both intertheater and intratheater mobility, with emphasis on the latter). Perhaps, the C-17 can provide some capability for intratheater mobility. However, even with a extensive use of C-17s, only small numbers of traditional mechanized (heavy) forces would be quickly deployable, perhaps at too high a risk.[13] Thus, one other possibility is to rethink how ground vehicles might be reconfigured for quick response, through early planning and consideration of how they might integrate, from a system perspective, with future intratheater lifters (e.g., C-130J,

[11]It is envisioned that dismounted enemy forces in foliage and urban areas, and information warfare systems targeting information networks, will be particularly difficult to counter-countermeasure.

[12]Currently, SEAD can take many days to perform, precluding the immediate positioning of ground forces behind enemy lines.

[13]In addition to providing intertheater lift, the C-17 was developed with the intent to provide intratheater lift capability; however, current planning suggests that the aircraft now will not be used in this way.

super-short takeoff and landing (SSTOL) aircraft, and other emerging concepts).

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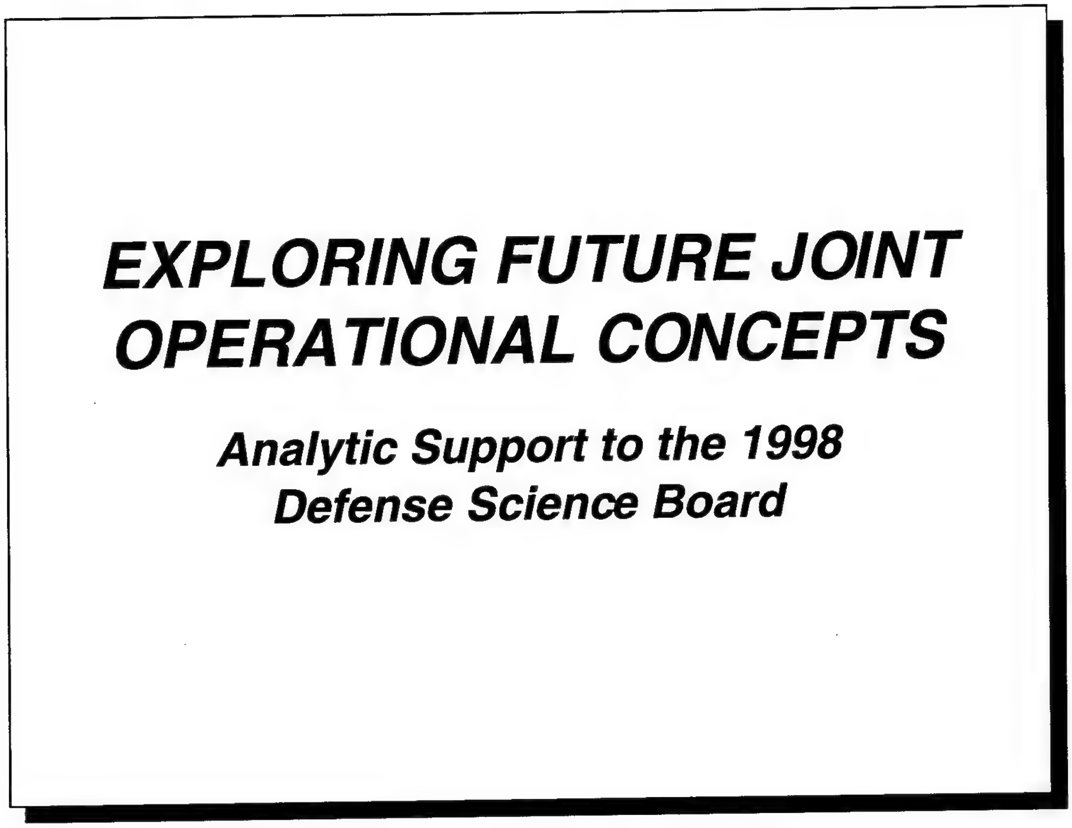
ABBREVIATIONS

AAA	Anti-Aircraft Artillery
AAN	Army After Next
ADA	Air Defense Artillery
AEFOG-M	Advanced, Enhanced Fiber-Optic Guided Missile
AFSC	Armed Forces Staff College
ARG	Amphibious Ready Group
ASP	Acoustic Sensor Program
BDA	Battle Damage Assessment
C2	Command and Control
C2V	Command and Control Vehicle
C3	Command, Control, and Communications
CAGIS	Cartographic Analysis and Geographic Information System
CBT	Combat
CS	Combat Support
DARPA	Defense Advanced Research Projects Agency
DIA	Defense Intelligence Agency
DSB	Defense Science Board
DCSOPS	Deputy Chief of Staff for Operations and Plans
DFAD	Digital Feature Attribute Data
DTED	Digital Terrain Elevation Data
ELINT	Electronic Intelligence
FA	Field Artillery
FARRP	Forward Aerial Refueling and Rearming Point
FCV	Future Combat Vehicle
FEBA	Forward Edge of Battle Area

FLOT	Forward Line of Own Troops
FFRDC	Federally Funded Research and Development Center
FOPEN	Foliage Penetration
FRV	Future Robotic Vehicle
FSV	Fire Support Vehicle
HPT	High-Priority Target
HUMINT	Human Intelligence
IFV	Infantry Fighting Vehicle
IRC	Immediate Ready Company
JV	Joint Vision
JSEAD	Joint Suppression of Enemy Air Defenses
JSOW	Joint Standoff Weapon
JSTARS	Joint Surveillance and Target Attack Radar System
JTF	Joint Task Force Commander
LGB	Laser Guided Bomb
LOC	Lines of Communication
LOS	Line of Sight
LOSAT	Line-of-Sight Anti-Tank
MADAM	Model to Assess Damage to Armor with Munitions
MANPADS	Man Portable Air Defense System
MEU	Marine Expeditionary Unit
MLRS	Multiple Launch Rocket System
MTMC	Military Traffic Management Command
MRR	Motorized Rifle Regiment
NDRI	National Defense Research Institute
NGIC	National Ground Intelligence Center
NVEOD	Night Vision Electro-Optical Division
RJARS	RAND's Jamming Aircraft and Radar Simulation
RSTA	Reconnaissance, Surveillance, and Target Acquisition

RTAM	RAND's Target Acquisition Model
SAM	Surface-to-Air Missile
SARDA	Secretary of the Army for Research, Development, and Acquisition
SEAD	Suppression of Enemy Air Defenses
SIGINT	Signal Intelligence
SOF	Special Operations Forces
SSTOL	Super Short Takeoff and Landing
SUO	Small Unit Operations
TACMS	Tactical Missile System
TEA	Transportation Engineering Agency
TGW	Terminally Guided Weapon
TOF	Time of Flight
TRAC	TRADOC Analysis Center
TRADOC	Training and Doctrine Command
WCMD	Wind-Corrected Munition Dispenser

1. Introduction



This annotated briefing summarizes one area of research that RAND performed for the Defense Science Board (DSB) to support the summer study task force on joint superiority operations. More specifically, this briefing describes the high-resolution constructive simulation effort that assessed different force concepts, as defined by: members of the DSB, the joint force community (e.g., Armed Forces Staff College), and various warfighters.

This research was conducted within the RAND Arroyo Center, Force Development and Technology Program, and the National Defense Research Institute (NDRI), Center for Acquisition and Technology Policy. It was formally sponsored by the U.S. Army, Office of the Deputy Chief of Staff for Operations and Plans, and by the Office of the Undersecretary of Defense for Acquisition and Technology. It was coordinated closely with GEN (ret.) David Maddox and Dr. Ted Gold, who were members of the DSB study representing the DSB in overseeing this effort.

Project Objective

- **Explore and assess joint operational concepts as defined by the Defense Science Board**
  - **High-intensity case**
  - **Quick-reaction scenario**
- **Help integrate research with higher-level DSB effort of shaping JV 2010**

The primary objective of this research was to quantitatively assess some joint concepts of operation consistent with Joint Vision (JV) 2010 that might be viable around the 2010–2015 time frame. Although the DSB task force was asked to explore joint operations from a very broad perspective (see "Terms of Reference," footnote 1, page vii), including low-, mid-, and high-intensity operations, the scope of this work was limited to only the high-intensity case. It was envisioned that by exploring joint operational concepts, albeit within the context of a relatively narrow solution space, useful insights would emerge.

Four Emerging Joint Vision 2010 Operational Concepts Rely on Information Superiority

- ***Dominant maneuver***—**multidimensional application of information, engagement, and mobility capabilities to position and employ dispersed joint forces to accomplish operational tasks**
- ***Precision engagement***—**use of system-of-systems capabilities to locate an objective or target, provide responsive C2, generate desired effect, assess level of success, and retain flexibility to re-engage**
- ***Full-dimensional protection***—**control battlespace to ensure freedom of action during deployment, maneuver, and engagement, while providing multilayered defenses**
- ***Focused logistics***—**fusion of information, logistics, and transportation technologies to provide rapid crisis response, to track and shift assets even while en route, and deliver tailored logistics packages and sustainment**

Four operational concepts that represent the backbone of JV 2010 include: dominant maneuver, precision engagement, full-dimensional protection, and focused logistics. Information superiority, involving improvements in communication, navigation, surveillance, weapons support, information control, and logistics support, is defined as a critical capability, which will help to enable the four concepts in the future. Although these concepts provide overarching guidance for shaping a joint force for the future, they provide enough flexibility for many interpretations. Perhaps this was by intention.

We planned to examine one possible set of interpretations of these joint operational concepts within a very specific scenario and situation. By doing so, we hoped to expand a much-needed dialogue on what JV 2010 might mean from an implementation perspective and how defense decisionmakers might respond to activate some of the ideas within it.

Research Questions
(RAND High-Resolution Analysis)

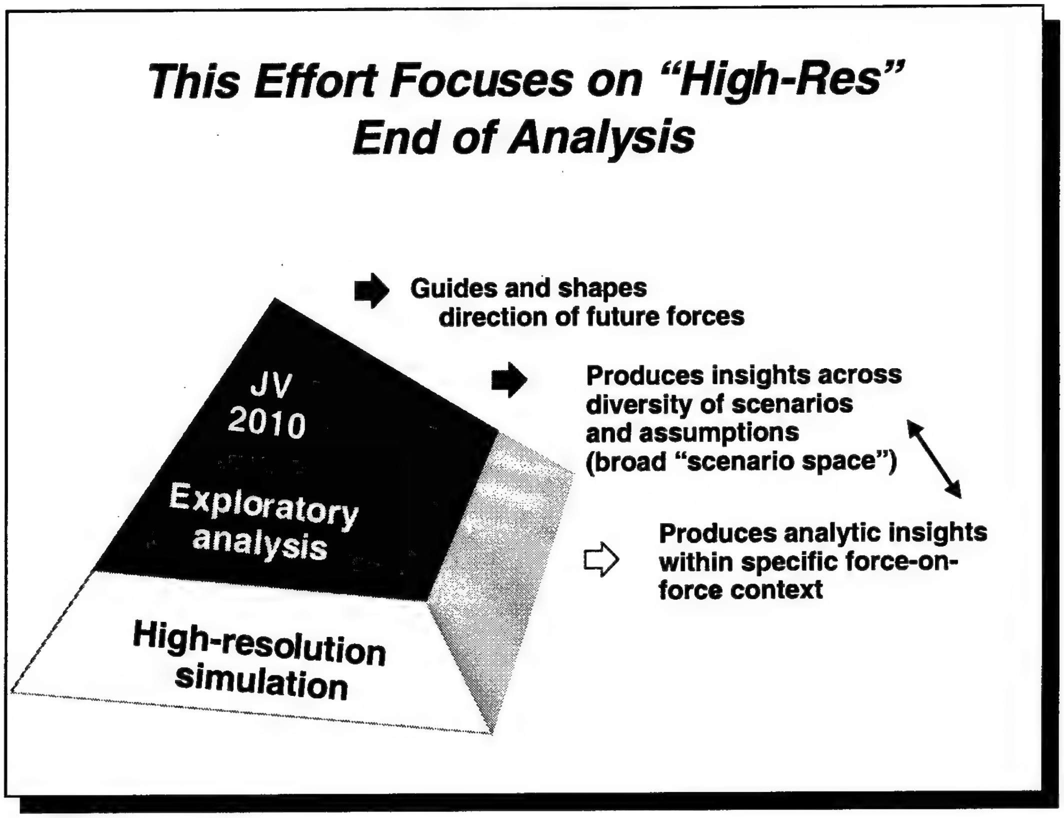
- How can improved decisionmaking (via RSTA and C2 capabilities) enhance future Joint operations?
- How should we think about the relationship between maneuver and firepower?
- What are the major factors affecting Joint force effectiveness?

Key questions the DSB asked RAND to address delve into two specific areas. First, we were asked to examine the possible impact of information superiority on future joint operations. Noting that information superiority is a relatively broad term, we broke it up into two distinguishable, assessable components—reconnaissance, surveillance, and target acquisition (RSTA) capabilities[1] and command and control (C2) capabilities (with communications implicit).

Second, we were asked how improvements in RSTA and C2 might affect future maneuver and engagement capabilities and, as a result, how they should be changed to exploit information superiority. Considerable work has been done on engagement, and in the wake of the Persian Gulf War, the perception is that engagement has outpaced other aspects of warfare (e.g., the critical factor is no longer firepower, but rather the ability to direct it). There also is the perception that maneuver, as essential as it is seen to be, is too difficult to assess with today's analytic tools and, therefore, does not generally get assessed properly.

The third question represents an open-ended request that we consider and raise as many as possible implications of actions or conditions that could impair force performance. These may include enemy countermeasures, environmental conditions, or even poor decisionmaking.

[1]We also assume Blue has access to intelligence inputs contributing to an intelligence preparation of the battlefield and an estimate of the enemy order of battle.



Although our work began by focusing on a detailed examination of joint operational concepts using high-resolution, constructive simulation, this work was later integrated (to the extent possible given the time available) with a more exploratory multiresolution approach suggested by recent RAND research.[2] This work supports the DSB from a broader perspective, examining larger-scale issues. This in turn was used by the teams to help with the higher-level tasks of shaping JV 2010. Results from the RAND exploratory work will be published separately.[3] A summary integration is included in Vol. 2 with the Team C report.

[2]See P.K. Davis, D. Gompert, R.J. Hillestad, and S. Johnson, *Transforming the Force: Suggestions for DoD Strategy*, Santa Monica, CA: RAND, IP-179, 1998.

[3]The forthcoming RAND research will be entitled "Exploratory Analysis of Future Joint Operational Concepts: Analytic Support to the 1998 Defense Science Board Study."

2. Scenario

Outline

- **Scenario**
- **Approach**
- **Results**
- **Insights**

This annotated briefing is divided into four major sections. In this first section, we describe the scenario for which joint operational concepts will be conceived and assessed. Next, we describe our analytic approach using high-resolution simulation. We will then summarize our interim results and finish with a discussion of emerging insights and future directions.

Motivations for Scenario Adopted

- **Interest in examining deep attack operations with:**
  - **Relatively shallow battlespace**
  - **Mixed terrain**
  - **Early "offensive" ground-force operations**

Getting away from Desert Storm revisited

- **Examining issues for which detailed simulation is particularly important**
  - **Value of RSTA and improved decision processes**
  - **Feasibility and effectiveness of alternative operational concepts and weapons**
  - **Synergism of long-range fires and maneuver with small precision-fire forces**
- **Practicalities: available databases, leveraging ongoing research**

With the limited time available for this analysis, we chose to focus on a single scenario. The particular one used was selected because it was stressing, it exercised all the aspects of JV 2010, and it was available from an ongoing Army research effort.

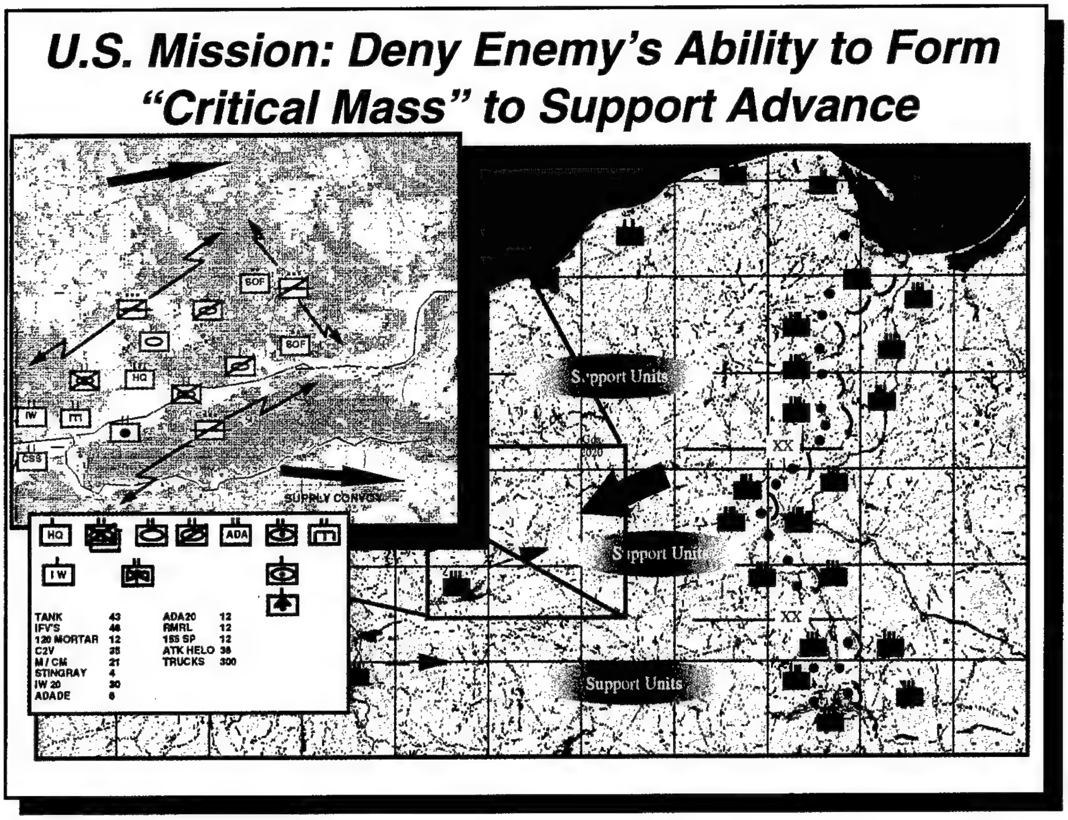
The scale and topography lent itself well to deep attack operations. The battlespace is, by some interpretations, relatively shallow (several hundred km), yet large enough to encourage joint operations and elements of maneuver. The terrain is also sheltered enough to provide cover for an advance, unlike Desert Storm.

Objectives and Strategy Assumed for Analysis

- **Friendly force objectives—quickly stop enemy advance, weaken his forces, and gain initiative**
- **U.S. application of Joint force**
  - **Establish theater defenses, support allies with liaison teams, conduct SEAD, conduct strategic bombing,...[not simulated here]**
  - **Apply variety of long-range fires immediately**
  - **Attack into enemy's rear almost immediately to help cause attrition, break momentum, and seize the initiative**

The scenario and situation that we proposed to examine future joint operational concepts is described over the next several charts. First, we stipulate that this scenario is a highly stressing one for the United States. It is representative of a difficult, quick-reaction situation in which U.S. forces are committed to respond to an aggressive threat in the 2010–2015 time frame. Generally, it requires the United States to establish control throughout the depth of the battlespace and to quickly regain the initiative at the operational level. This begins with a series of actions that are not modeled and are assumed to be successful—linking up with the coalition forces, carrying out suppression of enemy air defenses (SEAD) operations, and gaining air superiority. The application of Joint force we examine in detail consists of a combination of standoff, long-range fires, and operational maneuver.

Although the scenario is hypothetical, we used an existing digital database for mixed terrain (East Europe), and we consulted various organizations such as the Defense Intelligence Agency (DIA) and the National Ground Intelligence Center (NGIC) to help us shape a notional adversary's capabilities, composition, and application of force in this time frame. The next chart will describe the scenario and U.S. mission in more detail.



The situation shown above is about five days into the enemy advance. The enemy mechanized units have been slowed by what might be considered a conventional coalition defensive force. (The area of engagement shown above is several hundred kilometers on a side, with grid lines shown at 50 km in the image.) The mission of the U.S. forces requires the rapid establishment of control at depth within the battlespace. More specifically, the assumed U.S. operational mission is to stop the elite enemy division, starting with the lead regiment (shown by the insert) that is en route to providing reinforcement to the salient shown above.[4] There is an element of urgency in this situation. It is assumed that if the elite enemy division reaches the front at strength it will have the power to rupture the line of the U.S. ally. Opportunities to engage the enemy are limited, however, due to the mixed, foliated terrain.

Success in this scenario requires the United States to project power very quickly well behind enemy lines. Although this would likely be implausible with today's forces and associated capabilities, it is envisioned that a combination of maneuver (strategic, operational, and tactical), precision engagement, full-dimensional protection, focused logistics, and information superiority, in conjunction with new or enabling technologies, can allow identification of a set of possible "solutions."

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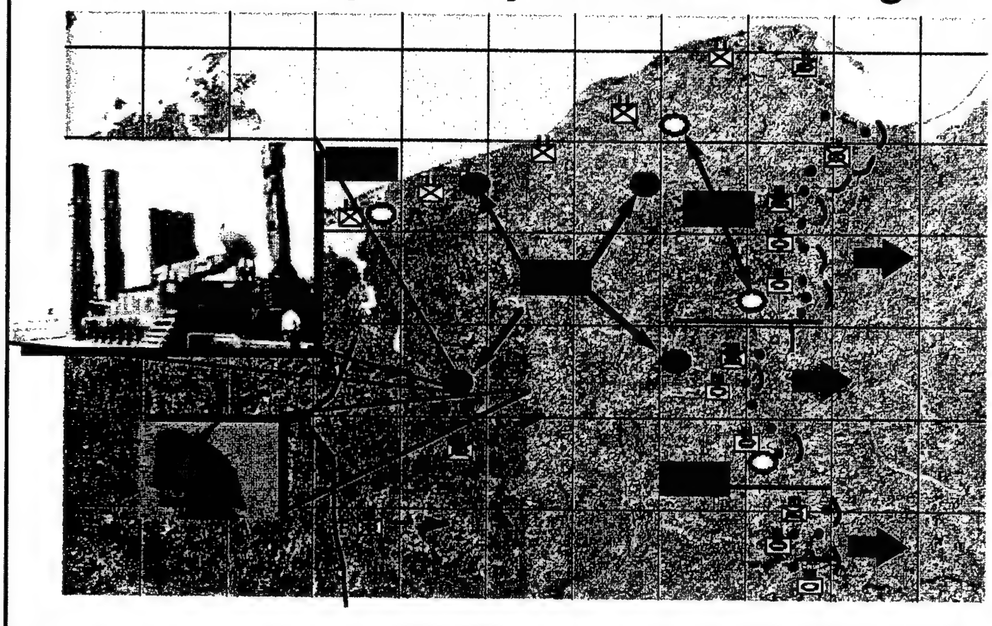
[4] The U.S. forces could operate conventionally, helping to shore up the coalition defense by establishing a safe haven offshore in the northeast and deploying additional heavy forces and air power. Unfortunately, this would require excessive time for build-up, and the coalition force is near breaking.

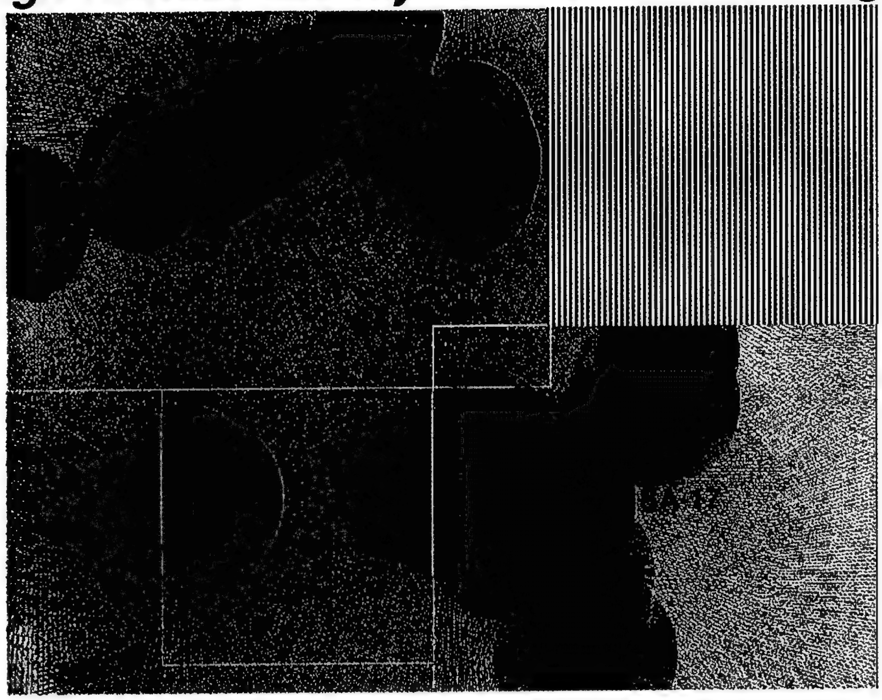
An Integrated Air Defense Network Is One of the Enemy's "Asymmetric" Strategies



One asymmetric strategy that a future threat is likely to employ to counter U.S. air power is a sophisticated integrated air defense network. For our threat, we presume that long-range, high-end systems such as Russian SA-12s and SA-17s are emplaced throughout the depth of the battlespace. Since these are relatively mobile, tactical surface-to-air missiles (SAMs), they can accompany the advancing mechanized formation. In addition to these long-range systems, we include medium-range systems including SA-15s and short-range systems such as 2S6s, SA-18 man-portable air defense systems (MANPADS), and anti-aircraft artillery (AAA) in the network.

Although these air defenses operate in a stand-alone mode and can be quite formidable, they can become a significantly greater challenge when integrated. More specifically, these air defenses are represented as "partially integrated" in our simulation. A number of early-warning radars (both air- and ground-based) are emplaced throughout the depth of the battlefield. These systems can provide cueing to the SAMs, allowing the SAMs to remain quiescent and thus more difficult to find. Some systems such as MANPADS, which tend to be nonemitting (and very dangerous to low-flying helicopters and airlifters), it is unlikely that their locations will be known in the 2015 time frame.

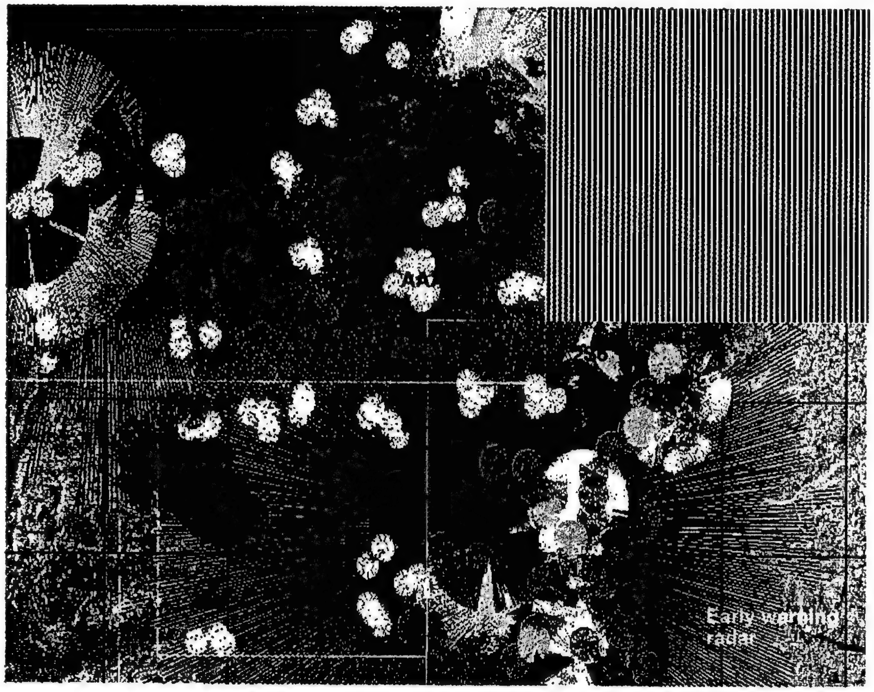
High-Altitude Enemy Air Defense Coverage



The above chart depicts the enemy air defense coverage patterns at medium altitude, approximately 20,000 feet. The long-range early-warning radar coverages are shown in blue and purple, SA-12s are shown in green, and SA-17s are in yellow. The medium-range SA-15s (shown in red) cover the areas over the coast and the enemy front line. The region in the northeast is not considered here, as it is assumed to be covered by an adjoining enemy unit.

Attacking and taking down at least part of this integrated air defense network appears to be a necessary first step. There are a number of methods by which this can be accomplished today; however, the enemy is likely to take steps to protect this asymmetric strategy well into the future.

Low-Altitude Enemy Air Defense Coverage



In contrast to the previous chart, this one shows the coverage pattern of the same air space but at much lower altitude, approximately 100 feet. Here, it is evident that the coverage of the long-range systems is substantially reduced because of line-of-sight (LOS) limitations. Nonetheless, even with reduced coverage, the overall numbers of systems to contend with, resulting in considerable redundancies of coverage, can be overwhelming to a pilot attempting to penetrate air space at this altitude.[5]

Drawing on previous analysis, the density and lethality of the enemy air defenses in this scenario will likely require a combination of SEAD, reduced airframe signature, and special flight profiles to ensure survivability. In all of the concepts we examined, we intended to separate the SEAD issue from those that we addressed. Thus, survivability in this enemy airspace was assumed.

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[5] Number, density, and placement of air defense units shown here were coordinated with representatives of both DIA and NGIC.

3. Approach

Outline

- **Scenario**
- **Approach**
- **Results**
- **Insights**

This next section describes the basic research approach we used.

Three Critical Steps of This Research

- **Parametrically define different RSTA and C2 capabilities**
  - **Low, mid, and near-perfect at operational level and below**
- **Define joint operational concepts (firepower and maneuver)**
- **Analyze effectiveness of concepts**
  - **Interactive force-on-force assessment**

Enemy force capabilities kept constant (force design, organization, and support capabilities)

As noted previously, the two key dimensions of JV 2010 we are exploring are (1) the impact of RSTA and C2 on joint force decisionmaking quality, and (2) the importance of maneuver and engagement to these quick-reaction forces. The first dimension was examined parametrically, with values ranging from current (low) levels of information completeness, timeliness, and discrimination, up to a near-perfect bounding case, in which the commander has a complete and up-to-date picture of his own and the enemy's situation.

The second dimension varied the maneuver component, from a pure standoff attack operation using air power and standoff missile fires, to use of standoff attack complemented by deep insertion of ground forces. The first ground maneuver option (case 2) was an evolutionary one, proposed by representatives of the XVIII Airborne Corps and instructors at the Armed Forces Staff College. Here, the joint forces would establish a beachhead enabling a single combined arms maneuver battalion to be deployed and present a threat against the enemy elite units. This case 2 force was assumed to be armed with systems already projected in the services' POMs. The other ground options (cases 3 and 4) were more revolutionary, and more in keeping with notions of the DSB. Here, agile, dispersed ground components would be quickly inserted deep and would strike and maneuver against the vulnerable components of the elite units.

Defining RSTA and C2 Capabilities, Parametrically, by Their Components

Assumed RSTA capabilities

- **Low-level**
  - Coverage foliage/open: 0/40%
  - Accuracy*/discrimination: 200m/detect
  - Latency/update interval: 5 min/cont.
- **Mid-level**
  - Coverage foliage/open: 20%/70%
  - Accuracy*/discrimination: 100m/recognize
  - Latency/update interval: 1min/cont.
- **Near-perfect *(bounding case)***
  - Coverage foliage/open: 100%/100%
  - Accuracy*/discrimination: 1m/identify
  - Latency/update interval: real time/cont.

C2 capabilities

- **Nominal**
  - Fusion: 100%
  - Delay: 30 min
- **Fast**
  - Fusion: 100%
  - Delay: 5 min
- **Instantaneous**
  - Fusion: 100%
  - Delay: none

Assumption: canopied roads

*Since enemy movement is along road, correlation was assumed

RSTA and C2 capabilities tend to result from interactions of many factors, such as search areas and sensitivities of overhead assets such as the Joint Surveil-lance and Target Attack Radar System (JSTARS) and satellite sensors; inputs from signal intelligence (SIGINT); electronic intelligence (ELINT), and other indicators collected from air and ground platforms; degradations due to communications-relay delay times and losses, and effects of weather, terrain, and countermeasures. For simplicity in this short study, we postulated three parametric levels for RSTA and C2 capabilities, established by expert consensus, allowing us to roughly assess the importance of improvements in each of these.

The lowest level of RSTA was set to be conservative. No foliage penetration was assumed, about 40 percent of targets in the open could be detected and located but not recognized, and the time from detection to receipt of the information at the command center is five minutes. Enemy vehicles passed through many canopied areas even while they were on roads. The middle level improves the low level to 20 percent foliage penetration (FOPEN), 70 percent in open, recognition rather than detection only, and time of receipt drops to one minute. The near-perfect case was instituted to determine the extreme case—complete coverage at high accuracy, discrimination, and timeliness.

Command and control capabilities also started low, with a 30-minute delay for processing the information, deciding how to engage, and passing commands to a shooter. Flyout times are additional to this. The middle level drops the C2 delay to 5 minutes, and the bounding case has no time delay.

Representation of Different "RSTA" Levels in Constructive Simulation

Low-level *(detect only, no visibility into trees)*

Mid-level *(ability to recognize, some visibility into trees)*

Near-perfect *(ability to identify, complete visibility)*

These three images illustrate the differences in situation awareness with the three parametric levels of RSTA. The low-level case shows a portion of the enemy vehicles and does not differentiate them by type. The mid-level case shows more vehicles and categorizes them as track or wheel. The near-perfect case identifies all the vehicles and locates them precisely.[6]

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[6]Although it is difficult to see in this figure, a full-scale screen shot for the near-perfect case would show distinct icons for each type of vehicle. The mid-level case differentiates tracks and wheels with triangles and circles, and the low-level case simply indicates contacts with squares.

Operations Involve Extensive Use of Standoff Capability with Varying Levels of Maneuver

- **Case 1: Standoff Joint fires**
- **Case 2: Standoff Joint fires with ground insertion for blocking**
  - **1 Infantry Bn with RFPI-level of improvements**
  - **2 IRCs (M1s and M2s)**
- **Case 3: Standoff attack with agile ground maneuver attacking reinforcing division (attrition focus)**
- **Case 4: Standoff attack with agile ground maneuver attacking soft rear-area targets (disruption focus)**
  - **In 3 and 4: 10 teams of "SARDA mobile strike force" (FCV, FRV, and FSV) as surrogates for diverse Marine- and Army-concept forces**

The four operational concepts we consider are quite distinct in their level of maneuver and type of force application (all cases rely heavily on the aggressive use of standoff attack). Case 1 concentrates solely on standoff attack using bomber and F-15-delivered JSOW, along with Navy and Army versions of TACMS. These attempt to stop the advance of the elite enemy units.

Case 2 adds the insertion of a consolidated force (an advanced infantry battalion with two immediate ready companies (IRCs) to the standoff fires. This insertion requires establishing a lodgment and securing airfields for C-17s. Once in, the force flanks the enemy unit. The hope is that the enemy force will perceive this as a serious threat and turn to attack in response, detracting from its primary objective of reaching the forward line of own troops (FLOT).

Case 3 changes the picture to one of dispersed U.S. forces inserted deep to disrupt and attrit the enemy force at many points. This concept is one shared in many ways by USMC's Hunter Warrior , DARPA's small unit operations (SUO), TRADOC's AAN and Mobile Strike Force, and SARDA's Alternative Medium Weight Strike Force. The SARDA-defined force was the one we chose to use in this analysis. We employ a small ten-team force using three of the seven types of vehicles specified in the SARDA concept, described in more detail later.

Case 4 varies from case 3 only in application of force. Instead of using the agile maneuver forces against the enemy's combat forces, these forces concentrate on the "softer" logistics and supply vehicles.

General Features of Joint Concepts

- **JSEAD (not simulated here)**
- **Standoff fires (AF and Navy JSOW, and both Army and Navy TACMs) (simulated in some detail with human in loop for force-employment tactics versus sensible enemy regimental tactics)**
- **Insertion of ground-maneuver units (gamed as function of RSTA to assess subjectively feasibility and ability to find ambush sites or soft rear-area targets)**
- **Engagement of targets by ground-maneuver units (simulated)**

Each of the operational concepts we examined in this study requires a precise sequencing of events. Each of these events is accounted for (some through high-resolution simulation and gaming) differently. JSEAD and theater deployment are assumed to be successful for all four cases, so we do not assess them. Standoff, long-range precision fires [7] are modeled in detail, as are engagements between ground vehicles. Simulation of these includes quantitative characterization of sensing, movement, system delays, munitions effects, etc. Quality of insertion and extraction of ground-based maneuver units is determined subjectively for this study, based on off-line gaming.

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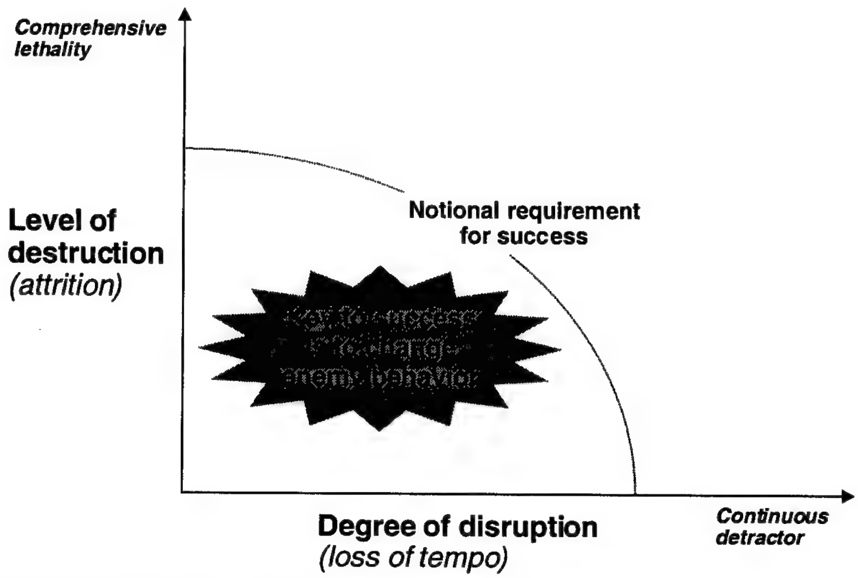
[7]JSOW was chosen to be representative of the types of munition dispensers available to Tac Air. Other options such as WCMD and TMD should provide greater delivery accuracy, but this advantage would have little impact due to the large-footprint submunitions carried. Also, riskier, low-altitude delivery of weapons such as LGBs was not considered, due to the expected risk.

Gaming and Simulation Were Used

Operation	Simulation	Man in Loop?	Comment
Enemy air and missile defenses air superiority, SEAD	No	Preplanning	SAM laydown represented to affect tactics
Enemy movement tactics	Yes	Yes	Sensible dispersal, "packeting," use of minor roads
Standoff attack with PGMs	Yes	Yes	Targeting dependent on RSTA, intell
Insertion of ground maneuver units	"Yes"	Preplanning	Sensible ambush sites, movement, extraction
Engagement by maneuver units	Yes	Yes	Targeting dependent on RSTA
Extraction	Yes	Preplanning	Survival simulated

More specifically, each of the phases of operation was simulated using a different combination of man-in-the-loop reactive actions or preplanned (scripted) responses. Enemy and U.S. force actions were planned and executed independently, by different members of the simulation team. These actions were affected by the degree of RSTA provided and the C2 delays assumed. As mentioned, suppression of enemy air defenses (SEAD) is assumed in this analysis. The amount of resources and time required to reduce enemy air defenses to an acceptable level could, however, be a very significant influence on U.S. ability to execute any of the four cases explored in this analysis.

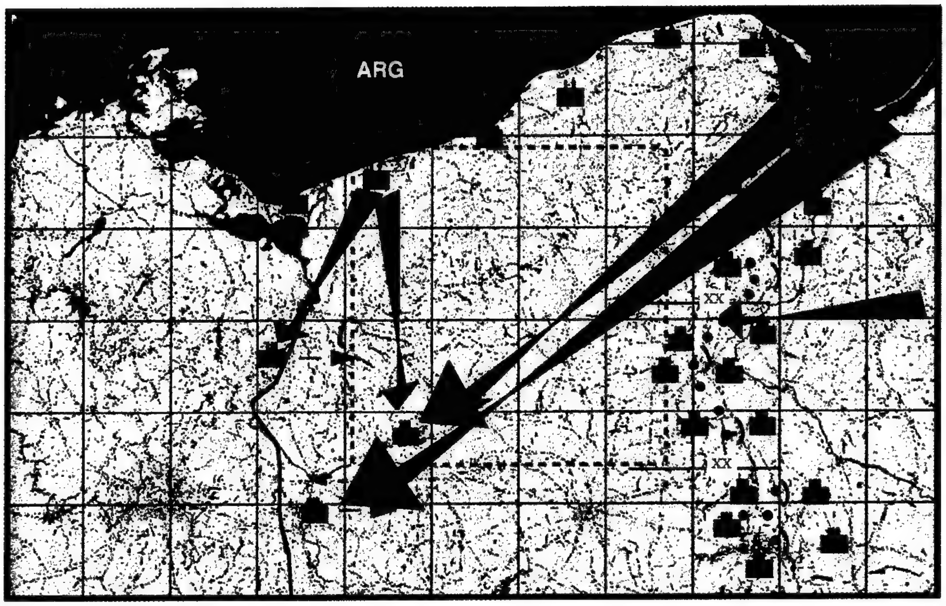
Effectiveness Can Be Gauged by Level of Destruction or Degree of Disruption



Assessments usually concentrate on enemy attrition (and own losses) as the primary measure of effectiveness (MOE), even though the dynamics of this engagement are such that disruption of the enemy operation—denying him the ability to move or resupply, slowing his progress, dispersing his forces, or degrading his coordination capabilities—may be as important as attrition. Shock effects (heavy losses over a short time, in small areas, or of key systems) may also disrupt the advance.

We will attempt to characterize the outcomes of the scenario along two dimensions—level of destruction and degree of disruption. As shown by the dotted curve in the figure above, many different combinations of these two factors may be sufficient to change enemy behavior. Success criteria for this curve tend to be subjective in nature.

Case 1: Standoff Attack Operation

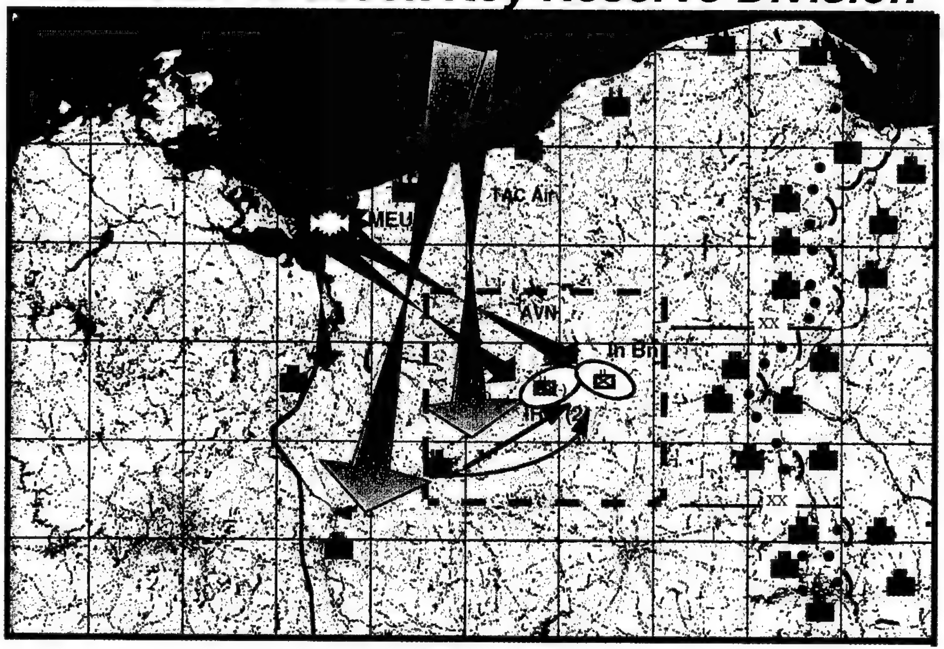


The stages of case 1 are delineated here. Generally, a joint-SEAD (JSEAD) operation aided by Special Operations Forces (SOF) opens air corridors to the target units. Army aviation bolsters the coalition defense along the FLOT. Naval missile fires from the amphibious ready group (ARG) concentrate on the lead and northern enemy units, while air strikes (bomber and F-15 with JSOW) attack the lead and southern units. The primary objective is to attrit the units sufficiently so that they cannot close with the units in contact.

Specific phases of the battle plan:

- U.S. air/helo/ground assets combined with coalition SEAD to open air corridor(s). SOF inserted to provide human intelligence (HUMINT) and battle damage assessment (BDA).
- Army attack helos destroy motorized rifle regiment (MRR) in center tank division along FLOT. U.S. infantry conducts infiltration in support along with limited air support and field artillery (FA). Marine expeditionary unit (MEU) seizes beach on north coast. U.S. air attacks attrit and slow lead and northern MRR (priority to lead).
- MEU attacks to defeat northern MRR. U.S. air shifts priority of attack to defeat southern MRR (80%) and continues to attack lead MRR.
- MEU continues attack on northern MRR. Air attack continues against southern MRR.

Case 2: Standoff Attack and Ground Insertion to Block Key Reserve Division

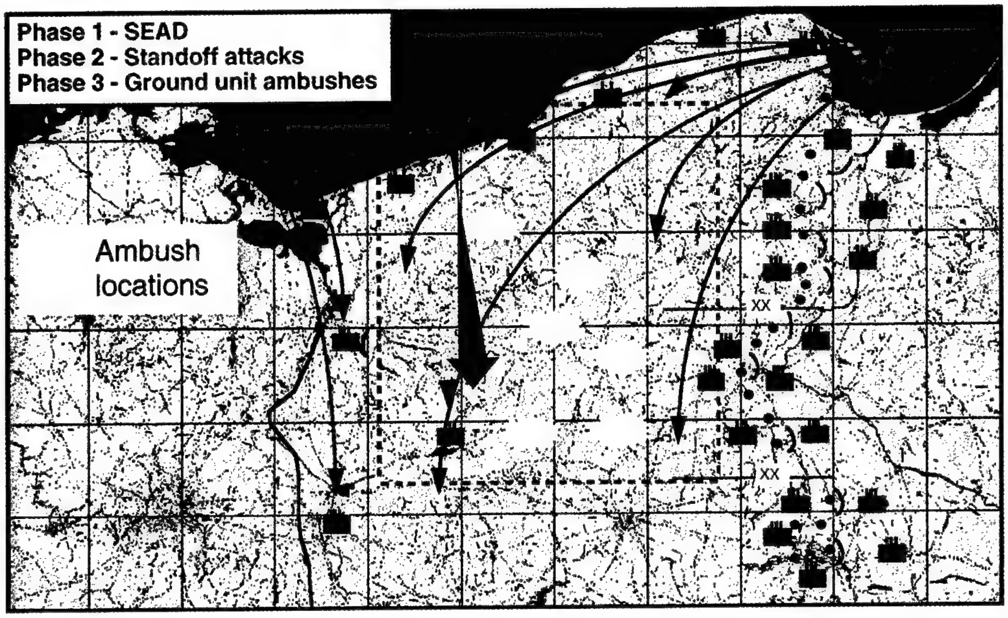


Case 2 also carries out the JSEAD and standoff attack missions, but it adds the insertion of a cohesive ground force. The ground force is made up of MEU and an airborne infantry battalion augmented with future systems such as AEFOG-M, LW-155, Outrider, and ADAS. The airborne battalion is augmented by two immediate ready companies (IRCs), which each have four M1s and four M2s (deployed with C-17s). The MEU first establishes a lodgment at the coast, enabling the Army ground force to be inserted to the flank of the lead elite enemy regiment. By enhancing its apparent size with deception devices, the IRCs try to provide a sufficient threat to turn the lead regiment. If successful, they use a combination of fire and maneuver to try to attrit and disrupt the enemy attack.

Specific phases of the battle plan:

- Begins with JSEAD and SOF insertion. Air begins attrition of lead MRR. MEU lands to establish lodgment and FARRP to north. IRC expands lodgment.
- ABN battalion establishes battle position north of lead MRR route of advance. IRC maneuvers to flank lead MRR.
- Combination of ground, rotary, and fixed-wing air attack MRRs to delay and then defeat.
- This creates a dilemma for the enemy commander by threatening his operation with a ground unit capable of physically interdicting lines of communication (LOCs) and destroying combat units.

Case 3: Standoff Attack and Agile Ground Maneuver To Engage Key Reserve Division



In case 3, standoff attack and quick-deploying maneuver forces are used to attrit and disrupt the enemy operation at many points. The JSEAD operation hits air defense sites throughout the region, and at the same time cuts a corridor through for an insertion. Standoff attacks target all of the elite units, while the ground units are deployed along the enemy's routes of advance. The ground units set up ambushes and plan for egress routes to their next attack points. Three types of enhanced medium-weight vehicles are used: future combat vehicles with LOSAT direct fire KE (kinetic energy) systems, fire support vehicles with advanced (30 km) fiber optic guided missiles, and robotic vehicles that can call in fires during the ambush and in the egress phase, in which they may be left behind. All of these systems can be airlifted by C-130s.

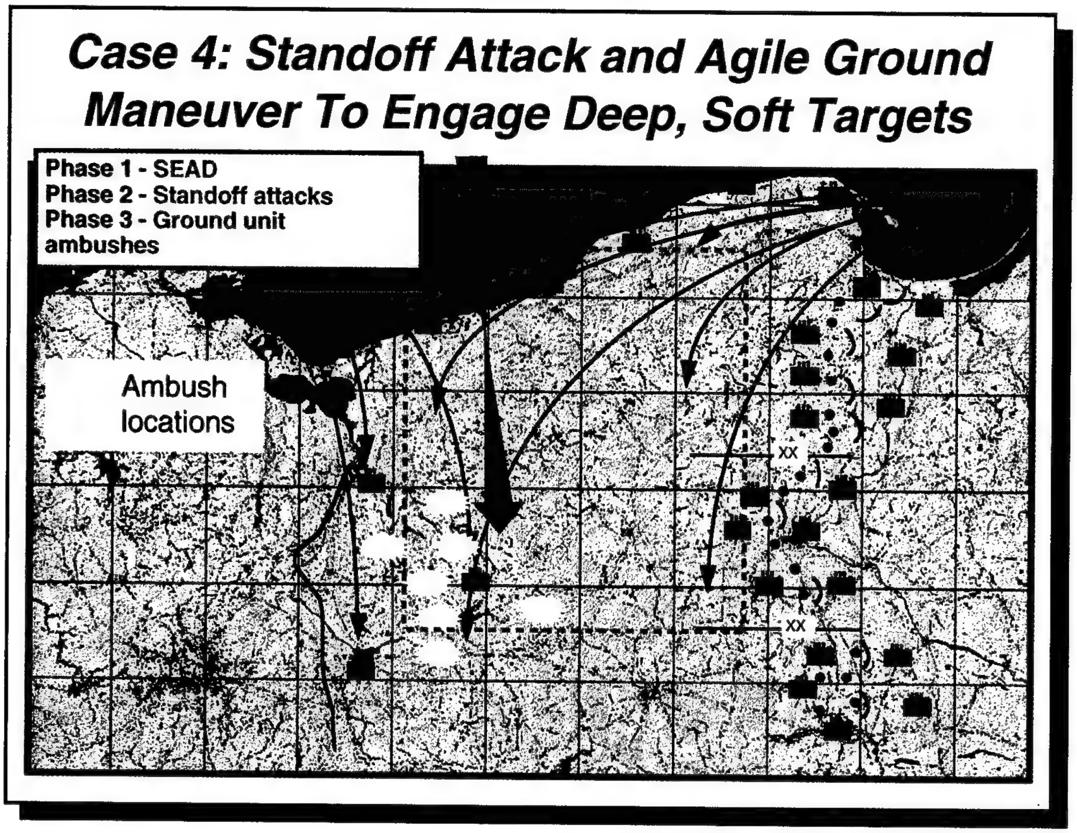
Specific phases of the battle plan:

- U.S. air/helo/ground assets combined with coalition JSEAD to open air corridor(s). SOF inserted to provide HUMINT and BDA.

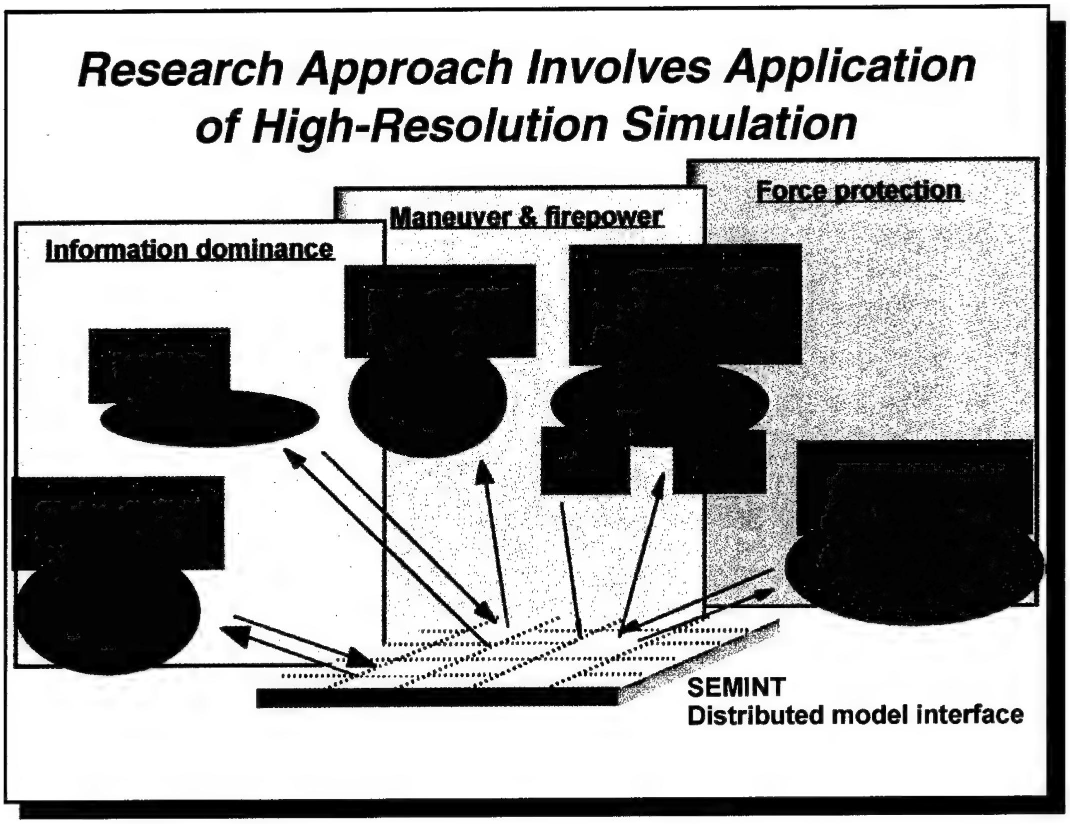
- Long-range standoff attacks conducted by Joint Task Force assets (both aviation and artillery).

- Light, highly maneuverable ground force conducts direct-fire ambushes to destroy the lead regiment.

- Air attack continues against northern and southern MRRs.



Case 4 appeared to be of greater interest than the other cases to the DSB. As in case 3, very agile ground maneuver forces are inserted to stop the deep elite enemy unit. However, the position of these forces is further to the west to directly engage the logistics and supply vehicles (more specifically, these include resupply trucks, C2 vehicles, self-propelled artillery units) which in this scenario, because of the great levels of dispersion, follow well behind the lead combat units. These "softer" targets are seen as being highly desirable targets, since any engagement of these forces would likely create havoc for enemy movement while minimizing the risk of the attacking U.S. force (since these enemy units have substantially less combat power). However, because the agile U.S. forces will need to get past the enemy combat units, getting to these soft targets requires a certain level of "stealthiness."



The basic models we used are shown above. Generally, they include a force-on-force combat model (Janus) with several "attached" models such as MADAM (Model to Assess Damage to Armor with Munitions, a model for simulated emerging smart and brilliant munitions), a C3 model (for better assessing the impact and degradations of C3), and a newly created active protection model. Other models include: CAGIS (the Cartographic Analysis and Geographic Information System, used for enhanced digital terrain representation), ASP (the Acoustic Sensor Program, for modeling acoustic sensor phenomenology), RTAM (RAND's Target Acquisition Model, for enhanced target acquisition techniques), and RJARS (RAND's Jamming Aircraft and Radar Simulation, for simulated surface-to-air interactions).

We analyzed the various conditions using the high-resolution simulation tools identified above. With the exception of the broad levels of RSTA and C2 (which were simulated parametrically), each entity was represented at the system level, including individual tanks, air defenses, aircraft, missiles, etc. The scenario was set up interactively using experienced military personnel, including Janus gamers and one of our RAND military fellows. Individual excursions were then run over a large number of iterations (typically 30) to arrive at a statistically stable sample of the stochastic outcomes. Several measures of effectiveness beyond that of simple attrition were used in the analysis. In this way, some attempt was made to capture the effects of disruption, delay, and selective targeting of key assets.

For Now, Use Simulation To "Think About" Disruption In Addition to Attrition

- **Can the forces be inserted and extracted?**
- **Can they find good, soft, "support" targets?**
- **What is the impact of engaging moving combat-support vehicles?**
- **Can they materially influence effects of long-range fires? (What do "eyes on ground" add?)**
- **Can they even do direct attack on combat forces?**
- **How important are (1) tactical mobility, (2) RSTA, (3) organic weapons, (4) long-range fire's responsiveness?**

In this study, the high-resolution simulation was not intended to provide definitive assessments of the utility of single technologies or capabilities. Rather, it was envisioned to serve as a tool for providing insights on the key aspects of future operations—the challenges of operational and tactical mobility and maneuverability, the challenges of coordinating long-range precision fires and agile ground maneuver elements, and the potential payoff for improved RSTA and C2 capabilities.

We identified earlier both level-of-destruction and degree-of-disruption as possible measures of success in this scenario. To some extent, the latter still needs to be refined. Disruption in this scenario can be as effective as destruction, and possibly easier to achieve. The operational requirement is to prevent the enemy elite division from reaching the FLOT effectively (with the force and timing required). In this study, we use the simulation environment to help provide context for thinking about the disruption aspect of an operation, and on which enemy forces to concentrate maneuver and fires.

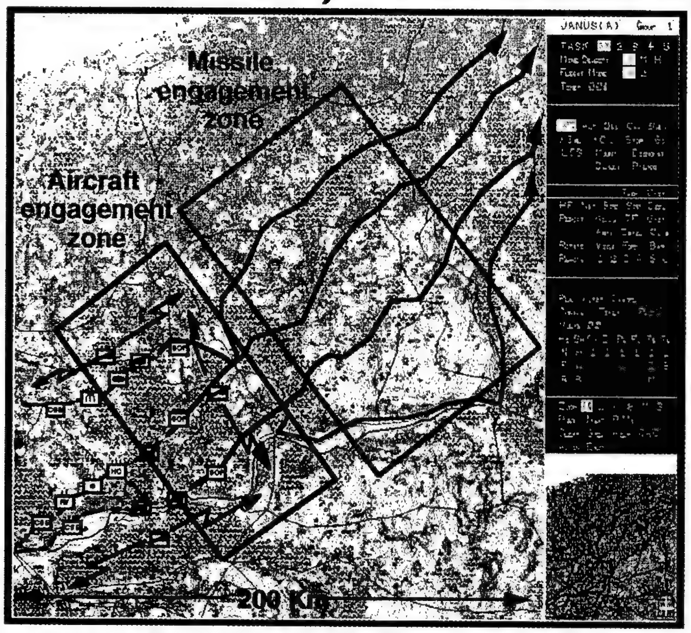
4. Results

Outline

- **Scenario**
- **Approach**
- **Results**
- **Insights**

This section summarizes our findings to date.

Case 1: Standoff Weapons (Aircraft and Missiles) Attack Lead Enemy MRR



Observations

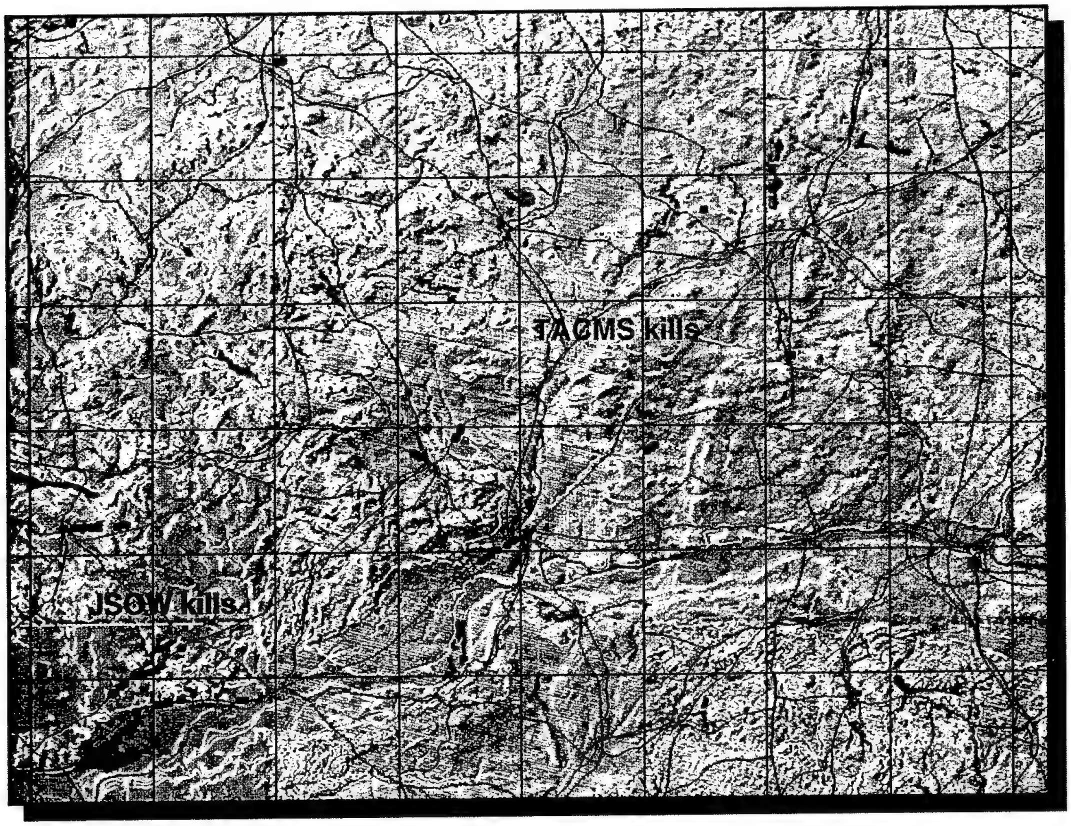
- **SEAD is critical part of the attack operation**
- **Deconfliction of airspace could result in better use of weapons**
- **Foliage represented a major limitation on placement/numbers of weapons**
- **Long cycle times (BDA) limited number of total engagements**

Could not decisively engage threat

For the standoff weapons case, the planners set up separate engagement zones for aircraft and missiles. This was done to ensure deconfliction of the assets. The aircraft launch their JSOW canisters from as far as 70 to 80 kms away, but this is still in the envelope of the long-range, high-end air defense systems. Accordingly, we assume JSEAD is successful against these emitters. The planners still have a difficult task targeting the smart munitions, as there are only limited open areas between covering foliage, and some amount of lead must be programmed into the targeting points to compensate for the weapon's long (10-minute) flyout time.[8]

The TACMS missiles also have difficulty with overhead cover and have a similarly long flyout time, because they are typically fired at almost maximum range. These weapons, equipped with brilliant submunitions, home in on the louder targets, such as tanks and BMPs.

[8] We assumed a 10-minute time-on-target, which might occur when lofting a subsonic-speed dispenser from moderate standoff range. Shorter timelines would occur from more dangerous close-range launches, or from update-in-flight capability (using comm links to the weapon).



This exemplary screen shot illustrates the cumulative locations of kills achieved by the two types of standoff weapons. The JSOW kills (shown in blue) concentrate on open areas in the southwest. TACMS kills (in red) are more spread out in the center of the engagement area, due to the smaller number of appropriate targets (loud tracked vehicles) and less predictable movements by the enemy during this interval.

CONDITIONS FOR TACMS ENGAGEMENTS

CASE 1 series	PROB (TREE)/ PROB (NO TREE)	LATENCY	BDA	C2 DELAY	TIME OF FLIGHT	TOTAL LEAD TIME	REMARKS
A	0.0/0.4 (LOW)	5 MIN	NO	5 MIN	10 MIN	20 MIN	SENSOR TO HQ
B	0.2/0.7 (MED)	1 MIN	NO	5 MIN	10 MIN	16 MIN	SENSOR TO HQ
C	1.0/1.0 (HIGH)	0 MIN	YES	5 MIN	10 MIN	15 MIN	SENSOR TO HQ BDA USED
D	0.0/0.4 (LOW)	5 MIN	NO	0 MIN	10 MIN	15 MIN	SENSOR TO SHOOTER
E	0.2/0.7 (MED)	1 MIN	NO	0 MIN	10 MIN	11 MIN	SENSOR TO SHOOTER
F	1.0/1.0 (HIGH)	0 MIN	YES	0 MIN	10 MIN	10 MIN	SENSOR TO SHOOTER BDA USED

RESULTS FOR JSOW AND TACMS ENGAGEMENTS*

CASE	JSOW FIRED	TACMS FIRED	JSOW CS KILLS	JSOW CBT KILLS	JSOW TOTAL KILLS	TACMS CS KILLS	TACMS CBT KILLS	TACMS TOTAL KILLS
A	144	40	33	7	40 (0.28)	2	16	18 (0.45)
B	144	60	34	6	40 (0.28)	1	19	20 (0.33)
C	144	68	33	7	40 (0.28)	2	21	23 (0.34)
D	144	40	34	6	40 (0.28)	3	29	32 (0.80)
E	144	48	34	6	40 (0.28)	1	25	26 (0.54)
F	144	68	33	10	43 (0.30)	4	32	36 (0.53)

*Each JSOW contained two submunitions; TACMS was assumed to carry multiple submunitions; numbers in parentheses represent efficiency per weapon.

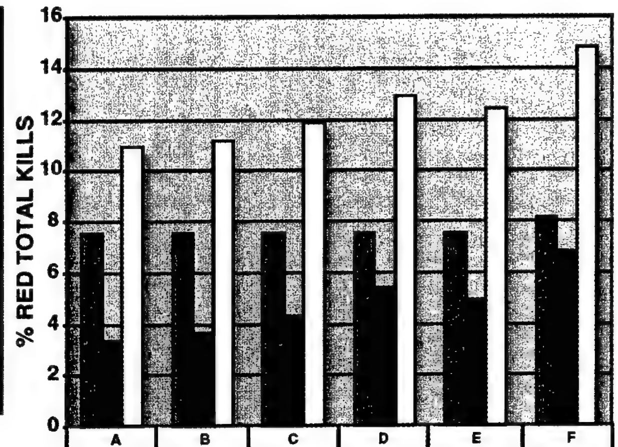
This chart displays the results of six different case 1 excursions involving different levels of RSTA and C2. Each excursion varied the level of detection probability (low, medium, and high) in both foliage and open areas. The timeliness of information (latency), engagement method decision time, and time of flight were also varied in each excursion. Only in cases of perfect information (high) was BDA (battle damage assessment) used in target planning. Here the planner observes the outcomes before targeting the next set of weapons.

Targeting methodology included the following steps: decide—choose location and number of missions fired based on number of HPTs (high-priority targets, consisting of six or more armored vehicles) and targets of opportunity; detect—track all HPTs or targets of opportunity for engagement in open areas along the three major avenues of approach; and deliver—fire missions into target areas with lead time calculated to interdict HPTs or targets of opportunity in open areas. Each JSOW contained 2 submunitions. Each fire mission used 2 TACMS per engagement with multiple submunitions.

Terrain and composition of target sets had a significant effect on TACMS efficiency. Advantages from better intelligence on enemy forces were hindered by the paucity of suitable target areas (open terrain) and ineffective destruction of vehicles with low acoustic signatures (CS vehicles). However, more TACMS were fired in cases with better intelligence, due to the target methodology used to engage HPTs and targets of opportunity.

Overwhelming Majority of Enemy Vehicles Survive Against Standoff Attack

In all cases only 11% of the CS vehicles were consistently destroyed by the JSOW due to limited target areas. The greatest effect on the total enemy force appears to be in cases D–F (shortest lead times) when CBT vehicle forces are degraded by more than 12%. However, this level of attrition would not ensure that Red forces are incapable of conducting future MRR level combat operations.



	A	B	C	D	E	F
■ JSOW TOTAL % KILLS	7.5	7.5	7.5	7.5	7.5	8.1
■ TACMS TOTAL % KILLS	3.3	3.6	4.3	5.4	4.9	6.8
□ TOTAL % KILLS	10.9	11.1	11.8	12.9	12.4	14.8

Decreasing sensor latency and C2 delay →

The greatest effect on the enemy appears to be in excursions D–F (shortest lead times) when the Red combat vehicle force was degraded by more than 12 percent. However, although the combination of improved intelligence and shorter "lead times" significantly improved the TACMS targeting effectiveness, the level of total Red attrition due to TACMS and JSOW kills never rose above 15 percent. Under the most advantageous conditions, the maximum level of attrition in case 1 was not sufficient to prevent Red forces from conducting future MRR-level combat operations and continue toward their objective.

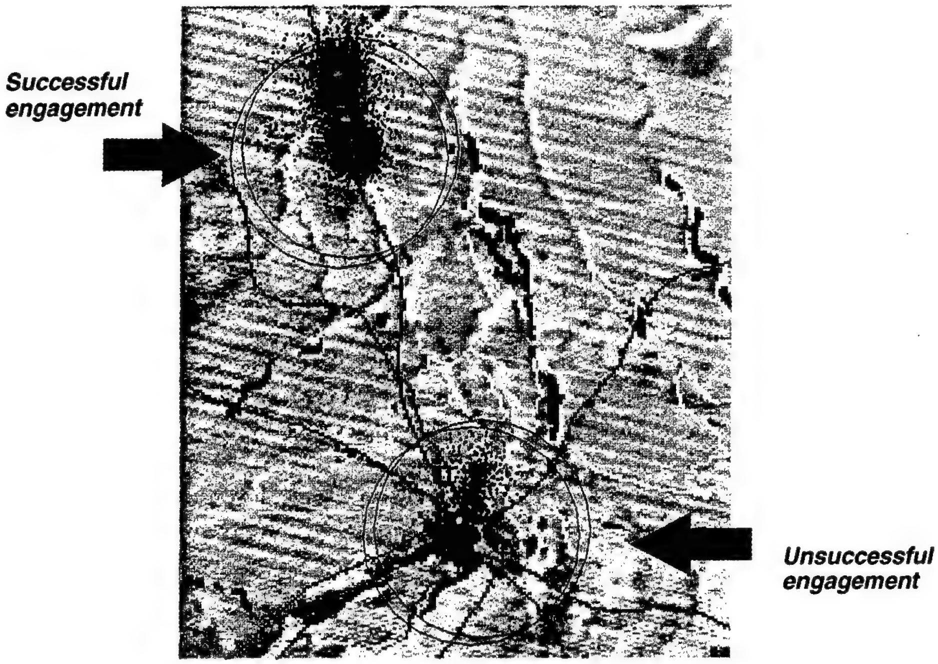
It should be noted that standoff attack might be improved with use of other tactics, such as riskier, low-altitude delivery of weapons, or use of orbiting alternative munitions. These options were not examined in this study, but they would be expected to be complicated by issues of SEAD, survivability, and deconfliction.

Reasons Why Standoff Attack Did Poorly, Even with Near-Perfect RSTA and C2

- **Threat is in highly dispersed formation to negate effects of massed strike (50–100 m vehicles, 1–4 km plt, 2–8 co)**
- **Foliage limited number of engagement opportunities**
- **Openings were not reattacked unless BDA indicated mission was incomplete (few dead targets in opening)**
- **With BDA imposed, long cycle times reduced numbers of possible engagements**
- **Long time of flight resulted in limited responsiveness—some targets were missed**
- **Submunition was not a good match for target set (sensors nonoptimal, dispersion logic imperfect)**

Standoff attack did poorly in this scenario. This cannot be attributed to RSTA and C2 capabilities, however, because even in the bounding case (comprehensive information, high level of accuracy, continuous update, no time delay), an average of less than one kill per weapon was achieved. This inefficient performance could be traced to six underlying factors, several of them scenario related, such as degree of threat dispersion (ability of the threat to "reshape" itself to appear to be a less lucrative target) and level of foliage on the terrain. Many of the factors had to do with the relatively long time-to-target associated with the use of these weapons at range. Others had to do with the logic associated with multiple-submunition weapon systems.

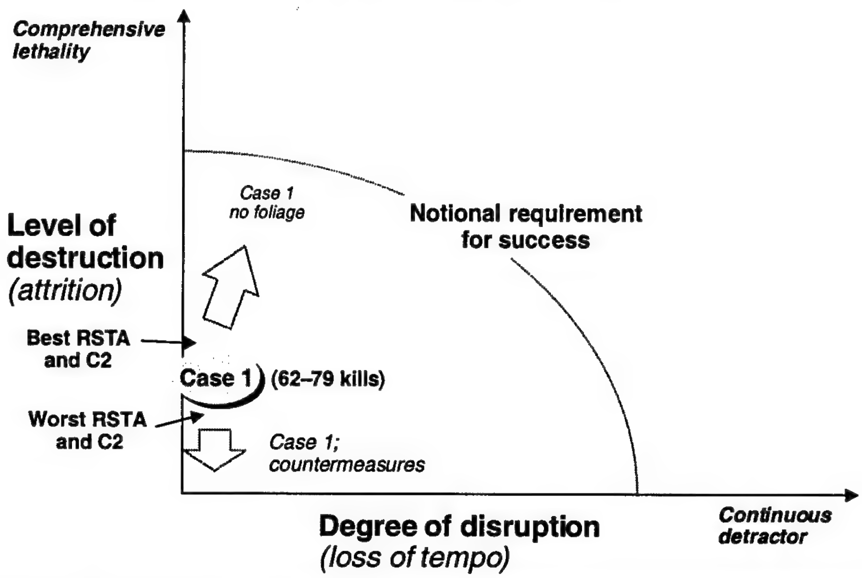
Illustration of Two TACMS Engagements



The sensitivity of TACMS to target set and environment is illustrated in the zoomed-in image shown above. At the north, TACMS is fired at a target set that is moving predictably on the road and is in a sufficiently long open area (2–3 kilometers) to guarantee encounter. The submunitions from two TACMS missiles make numerous acoustic detections, orient themselves along the column, and use their IR sensors to lock in on and kill several targets. At the south, however, two columns cross each other at a set of intersections. The forested and urban areas provide some cover, while the changing vehicle directions confuse the submunition distribution algorithm, resulting in some detections but no kills.

Altogether, Standoff Attack Operation Was Seen to Have Critical Limitations

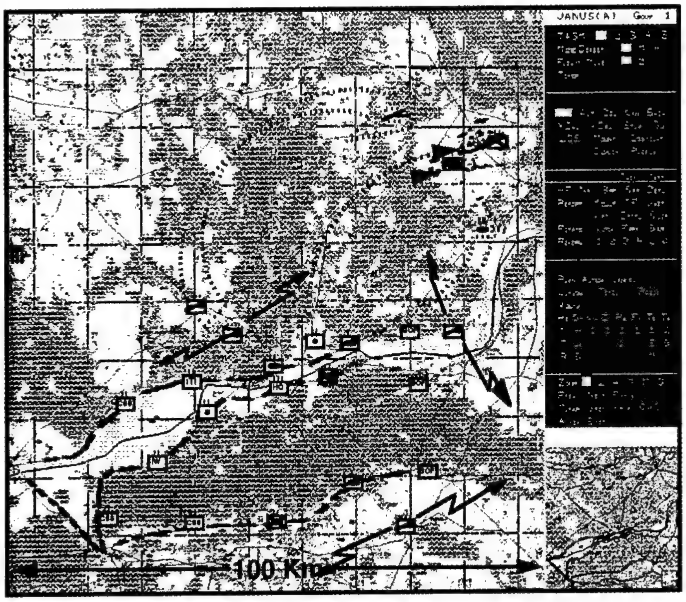
(Partly Due to Scenario/Terrain)



Plotting the outcome on the destruction/disruption axes discussed earlier, we find that standoff attack achieved a limited amount of attrition (killing 62 to 79 of the 550 enemy systems in the lead regiment). This level of attrition was found to increase strongly if foliage was omitted. We found, for example (in a separate "bald earth" run), that 195 kills were obtained. On the other hand, enemy countermeasures such as use of decoys, active protection systems, and force dispersion could reduce the kills below that achieved earlier.

In all these cases, the enemy might suffer little disruption. The standoff strikes seldom hit specific, high-value vehicles such as C2 or bridging assets, and do not have a localized "shock" effect. Rather, they attrit sporadically along the column, and the hulks would be expected to provide little obstacle to movement, particularly in this trafficable terrain. Only in the case with no cover would significant disruption be expected.

Case 2: Standoff Weapons and Airborne Ground Bn Divert Lead Enemy MRR



Observations

- **Enemy commander has options: engage with artillery, engage with artillery and ground forces, or bypass**
- **Ground force fails to accomplish assigned mission. Heavy losses are sustained.**
- **Blue cannot control the battlespace nor set conditions for success.**
- **Blue does not have the combat power, mobility, or firepower to engage enemy decisively**

Case 2 changes the situation dramatically, but only if Red chooses to turn and attack the battalion-sized force.[9] Even with two IRCs, the limited tactical mobility of this force renders it a relatively stationary, defense-based force. The screen shot shows the situation after the Marines have established a lodgment and secured airfields (to the north, not shown in this image), the Joint air operations have carried out SEAD on the insertion corridor, and the airborne battalion and two IRCs have been deployed to the northeast of the lead enemy regiment (shown in blue).

Once in, the U.S. force should have sufficient firepower to (1) present a serious threat to the enemy, (2) effectively engage (or at least delay) the enemy armor, and (3) successfully disengage and egress. If the force is bypassed, it does not accomplish its mission.

Assuming that the enemy turns to attack, when simulated, the results suggest that the ground force could substantially improve on the lethality obtainable by standoff fires alone. However, we note that part of the cost of this additional lethality comes in the form of losses to the ground force.

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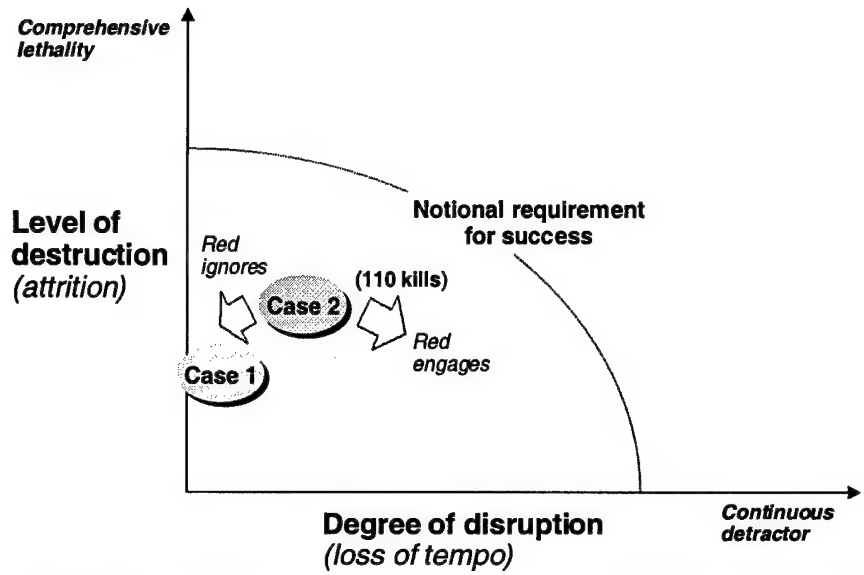
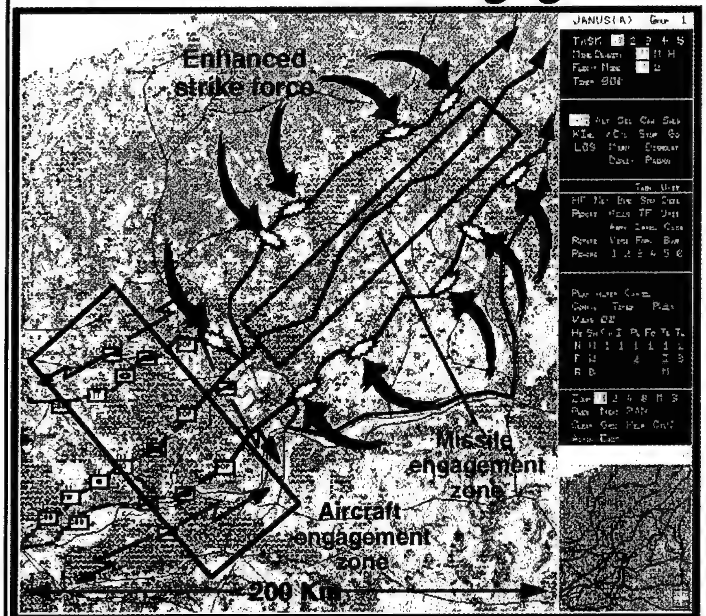
[9] One option available to the U.S. forces might be the use of electronic warfare methods to increase the signature of this relatively small force. By doing so, the increased signature might help to force an engagement by the enemy force.

Relatively Immobile Ground Force Results in Number of Options/Outcomes to Enemy



As indicated earlier, case 2 represents a substantial improvement on case 1. In addition to increasing the lethality of the U.S. response, it also increases the force's robustness, where weapons in close proximity (e.g., direct fire) can be significantly more difficult to countermeasure. Nonetheless, we note that this force, once in place, lacks mobility on par with the enemy, and thus it can be bypassed. Even if the enemy chooses to engage this force, depending on the circumstances it can opt to either fight with its overwhelming numbers or break off a smaller unit to contain this force.

Case 3: Standoff Weapons and Agile Maneuver Units Engage Lead Enemy MRR



Observations

- **SEAD is a critical part of the attack operation**
- **Deploying this force can represent separate challenge**
- **Timely and accurate RSTA and C2 is required to create ambush situation**
- **Direct and indirect fires allows successful completion of mission**
- **Some losses are inevitable**

"Reactive" Red cases must be examined

Case 3 represents a departure from the way a conventional ground force might operate today. Here, there is a deep insertion of advanced maneuver forces that attack the enemy forces at many points, executing ambushes and moving to the next engagement opportunity. This is done in concert with standoff fires. The aircraft engagement zone is as before, but the missile engagement zone is shifted to the middle column of the enemy advance. In this way, the large-footprint submunitions from standoff fires will not overlap onto friendly forces (minimizing fratricide).

Again, SEAD is critical to the mission. Enemy air defenses endanger the aircraft lofting JSOW, the transports inserting the ground forces, and even the TACMS missiles targeting the center column. Current levels of RSTA and C2 are probably insufficient to carry out this operation. The insertion requires extensive, up-to-date knowledge of enemy strength and locations. We only instituted "moderate" and "high" levels in these runs.

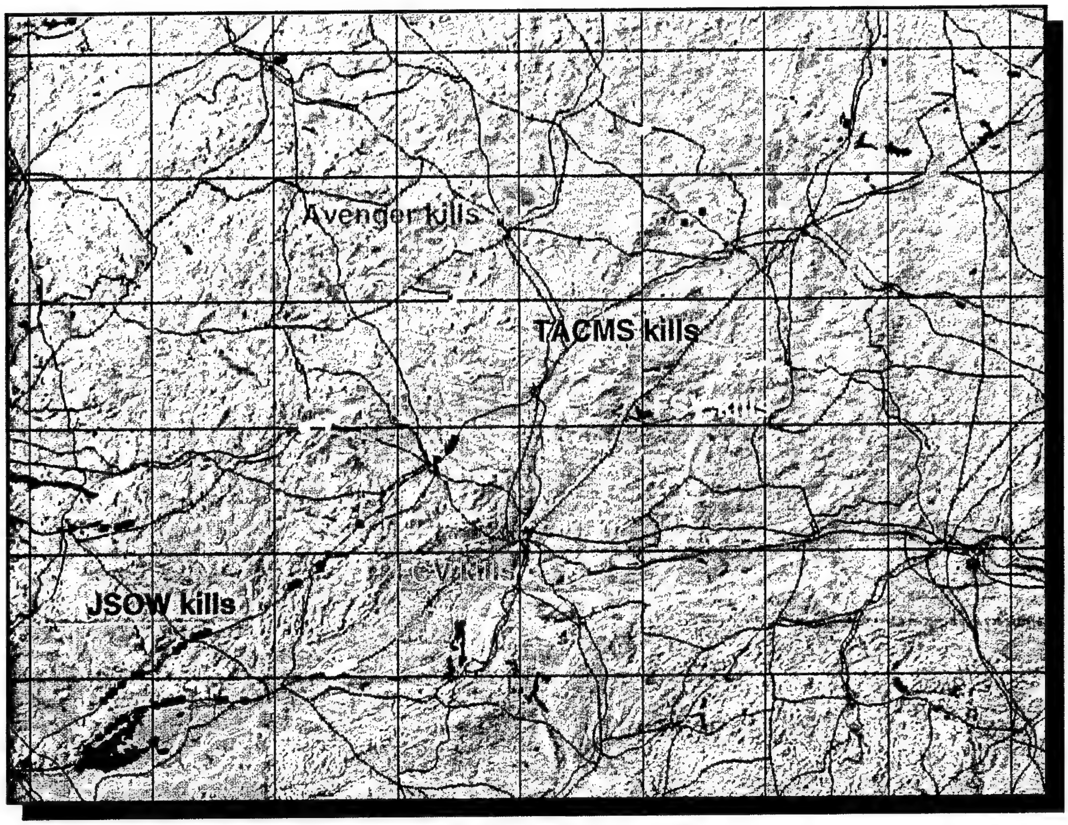
Given a successful insertion, we found that the combination of standoff fires and organic direct and indirect fires was very effective. Some losses were sustained by the U.S. ground forces, but the overall lethality of the combination of fires was far greater than for standoff weapons. One enemy countermeasure to this operation is to react to the ambushes by placing fire on likely further ambush locations. We found that this increased Blue losses but did not significantly change the outcome. Other countermeasures should also be explored.

Enhanced Strike Force (SARDA) Was Used as Representative Agile Maneuver Force

- **Family of vehicles based on 20+ ton chassis; airliftable on C-130s, C-17s, and C-5s**
- **Selected vehicles (three of seven) from SARDA force**
  - **Future combat vehicle (FCV) with LOSAT**
  - **Fire support vehicle (FSV-2) with AEFOG-M**
  - **Future robotic vehicle (FRV); did not include weapon**
- **Air defense vehicle, based on Avenger, was added**
- **Employed in task-organized teams**
  - **10 teams of 14 vehicles**
  - **Comprised of 7 FCVs, 4 FSV-2s, 2 FRVs (and 1 AD vehicle)**

Strategic mobility of this force appears to be favorable

We opted to use a new rapidly insertable and agile force defined by SARDA for our study. It is similar in some ways to TRADOC's AAN concept and Mobile Strike Force among other novel concepts for future warfare (e.g., USMC's Hunter Warrior and DARPA's Small Unit Operations); it relies on exploitation of many technologies. Generally this concept centers on a family of roughly 20+ ton tracked and wheeled vehicles that are airliftable on C-130s. Of the seven platforms currently envisioned for this notional force, we chose a subset for use in the scenario. Each of the ten teams in our organization has seven direct fire future combat vehicles, four fire support vehicles, two robotic scouts, and one air defense vehicle. The 140 total vehicles make up two battle units, roughly a third of a full battle force.



The Enhanced Medium Weight Strike force and standoff fires resulted in a lethal combination. This image shows the distribution of kills by each type of system. Kills by air-delivered JSOW occur first and are shown at the lower left. Shortly after, TACMS and the FSV (firing advanced fiber optic guided missiles) produced kills in the middle and outer columns, respectively, taking out much of the armor. Avenger resulted in a few helicopter kills, and the FCV (direct-fire LOSAT) completed the destruction in a series of ambushes. All told, about half of the enemy systems were destroyed.

Emplacing This Force in Enemy Terrain Can Be a Critical Challenge—Some Options

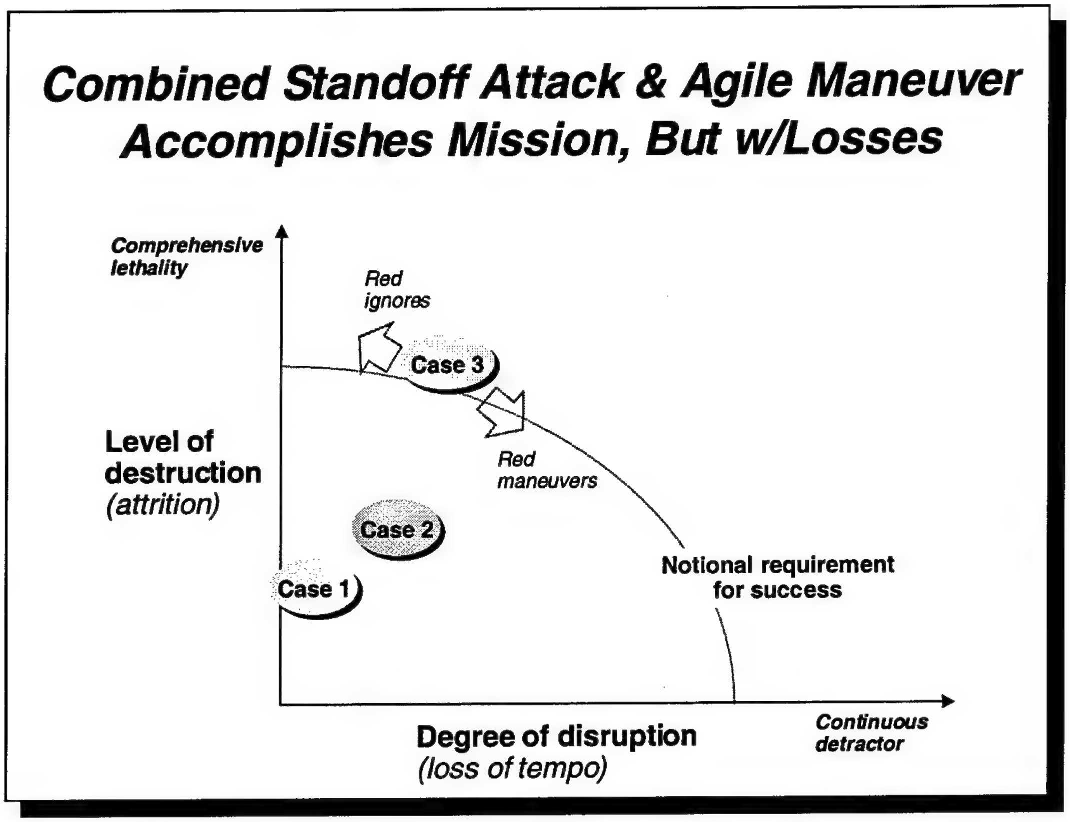
- **Allow enemy to bypass**
  - **Must be positioned very early in timeline**
  - **Relies heavily on force's ability to go undetected**
- **Deploy from the ground**
  - **Corridor on ground must be found/created**
  - **Special refueling methods may have to be developed**
- **Deploy from the air**
  - **Successful, early SEAD campaign is required**
  - **Airfield and perimeter must be secured first**

All options require logistics plan to be reconsidered

We noted earlier the difficulty of inserting a ground force deep in the enemy rear, given that Red would be expected to have a capable air defense network. Some alternatives to a direct, low-altitude insertion were also considered. The first possibility assumes good intelligence on planned enemy movements, along with an opportunity to insert prior to the invasion. The Blue maneuver force is stealthily inserted, waits for the attack, is bypassed, and initiates the ambush. In this and all other ground maneuver cases, extraction will require comprehensive intelligence and maintenance of secure air corridors.

The second, deployment from the ground, involves tactical air insertion to a region outside the enemy air defenses. Maneuver vehicles must then move quickly and stealthily to the engagement areas, and they may require in-route refueling points. Refueling may perhaps be accomplished using fuel bladders delivered by powered parafoils using GPS guidance.

Deployment from the air, finally, may be achieved using several means. The SEAD campaign may open several corridors, or there may simply be some weak points to the enemy perimeter. A set of airfields may be secured and multiple insertion areas established. The transport aircraft flight profile may entail high-altitude overflight (above the IR SAMs), followed by circling in on the landing areas. Depending on the degree of success of the air defense suppression effort, the ground force may have to be inserted against the enemy's flank and then maneuver toward the enemy. SEAD will have a large influence on how deep into the enemy array a ground force could be inserted.



Standoff with agile maneuver, in this scenario, achieved sufficient lethality to likely stop the Red force, even if disruption were not considered. Disruption was also present because of the shock associated with the ambush,[10] the ability of the direct fire and organic indirect fire systems to target specific high-value targets, and the presence of a capable force threatening the enemy rear that may force the opponent to change his plans.

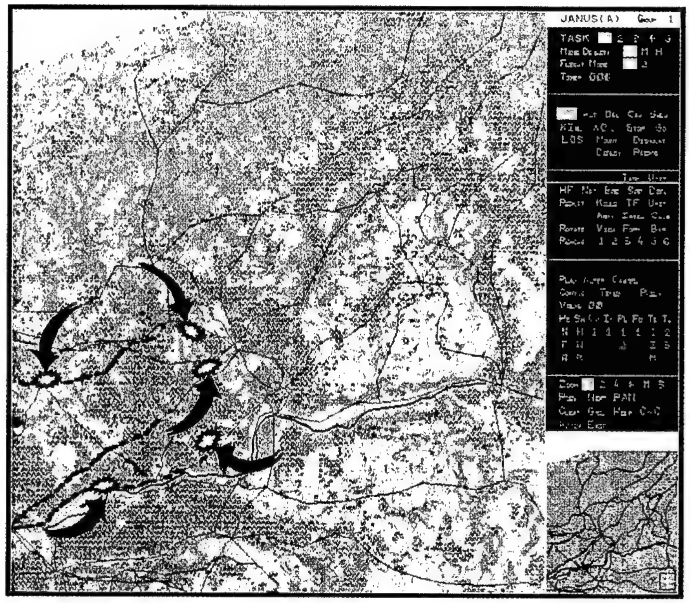
Red countermeasures will most likely reduce the impact of this force, but the effects would be limited because there are many different targeting mechanisms in case 3. These include long- and short-timeline systems, autonomous and man-in-the-loop control, seekers using different spectra, and direct fire systems able to sweep the battlefield. Standoff systems alone, on the other hand, utilize only a few different targeting modalities and thus would be expected to be more easily countered.

[10]Once the local ambush began, a large proportion of the kills were achieved within a relatively short time, roughly 5 minutes.

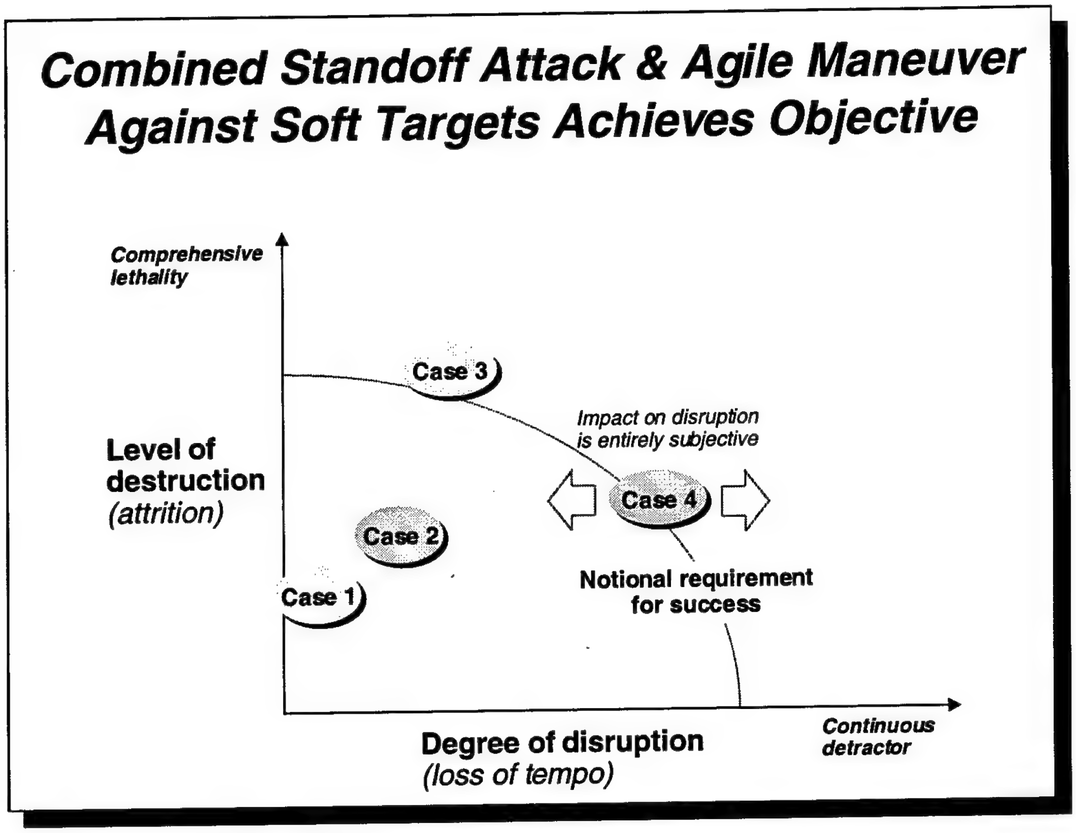
Case 4: Attack Can Be Focused on Support Entities Provided Enough Information Exists

Possible issues

- **How much information is needed to execute this kind of mission?**
- **Does attacking support vehicles have direct enough impact on enemy capability?**
- **How much agility is necessary for this force to successfully extricate?**

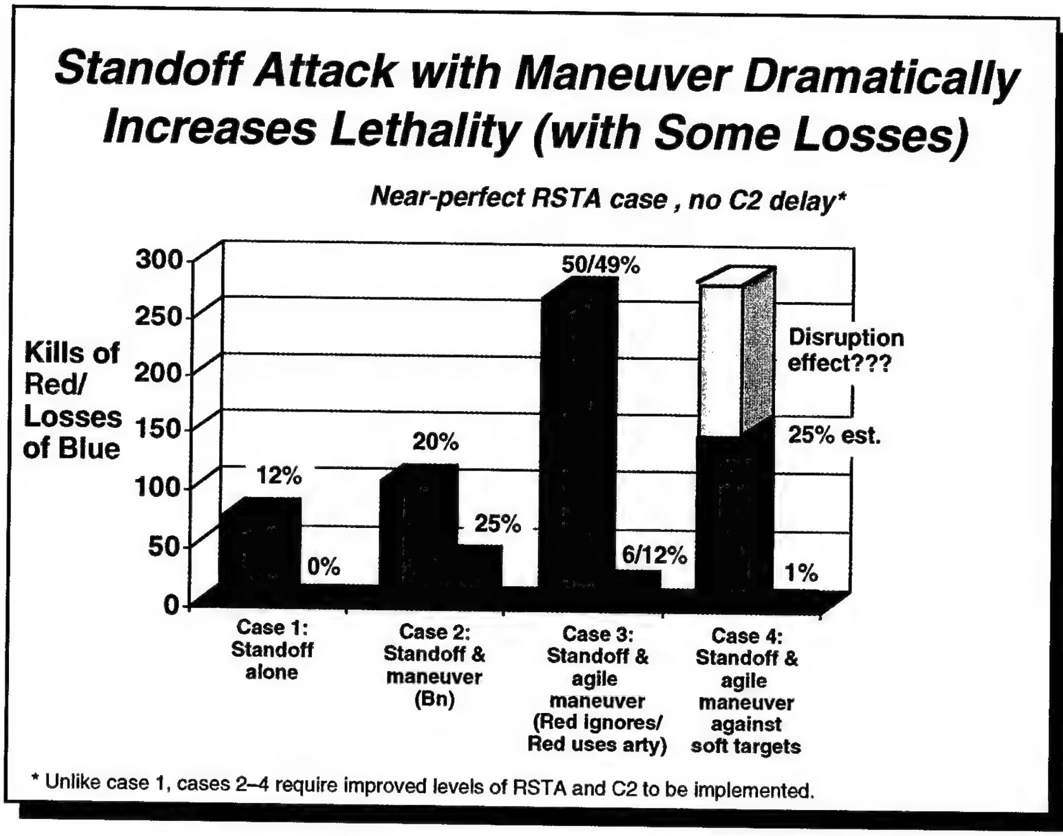


One shortcoming of the agile maneuver force is its vulnerability to massed direct fires. This may be avoided by attacking less dangerous elements such as resupply vehicles, C2 centers, AD sites, assembly areas, and artillery units. These should have a major impact on the enemy advance yet result in few U.S. losses, provided the agile maneuver units can extricate quickly after the attack. Preliminary runs with such a maneuver showed losses an order of magnitude fewer than when attacking similar-sized armor units.



Since the agile ground forces were competing with long-range standoff fires for the same more-lucrative logistics and supply vehicles (CS targets), overall lethality was not as high as seen in case 3. However, we note that because there was considerably more focused lethality on a specific target set, where all of the additional kills were directed against the soft logistics and supply vehicles, the effect of disruption would be significantly, perhaps exponentially, higher.[11] How much higher remains to be quantified. (To some extent, this may reinforce the notion that simulation tools, including the ones used here, tend to focus on attrition effects, which tend to be much more measurable. Other effects such as reduction in morale due to significant losses in short periods of time, for example, tend to be unaccounted for.)

[11] The additional kills were contained to the same target. Enemy CS losses were roughly 8 percent for case 1; for case 4, losses of CS were roughly 30 percent.



In summary, we note that case 1, which involved the aggressive use of standoff fires, resulted in a respectable 12 percent attrition against the overall enemy force. One advantage of this concept was that because direct exposure to the enemy was minimal, no losses occurred—assuming high-altitude JSEAD was successful. Case 2, which involved both standoff fires and what might be considered a conventional ground force insertion, provided increased lethality (and robustness), but at the cost of considerable losses to the U.S. force.

Case 3 represented a substantial increase in lethality from cases 1 and 2. The two variations of case 3 show different enemy reaction to the concept. If Red ignores the ambush and presses on, about 6 percent of the Blue force is lost, primarily direct fire FSVs. If Red reacts to the initial ambushes by stopping (resulting in significant delay) and directing fire support missions into ambush locations, U.S. losses increase. Organic direct and indirect fires each contributed as many kills as standoff fires. In fact, due to the shock of the ambush, enemy losses of less than 50 percent may well be sufficient to disrupt the enemy march. If so, fewer direct fire ambushes may need to be triggered, reducing U.S. losses further. Case 4 represents a significant departure from the way we think about assessing force effectiveness. Rather than a force-on-force engagement analysis, this tends to be a force effects analysis where most of the effects may be non-attrition-based. Thus, to some extent we have only begun to characterize the effects of this concept.

5. Insights

Outline

- Scenario
- Approach
- Results
- Insights

This final section describes general insights coming out of the analysis.

Insights from Research (1 of 2)
(RAND Scenario)

- **Combination of engagement and maneuver capabilities is required for joint force robustness**
  - **Standoff engagement offers tremendous potential to shape battle conditions, but comes with key physical limitations**
  - **Agile maneuver allows control of terrain and enemy action, but comes with inherent risk**
- **New RSTA and C2 capabilities can enable some concepts; for others, it will not be the critical factor**
- **With limited resources, choices need to be made between strategic and operational mobility. To some extent, these may offset each other**
- **Lighter ground force systems may be required for agile maneuver (quick-reaction) missions**
- **Weapons may be limiting factor for standoff engagement**

We were surprised to find that standoff attack using currently envisioned long-range ground, naval, and air-delivered weapons had limited effect. Weapons were seen to be poorly matched to the targeting opportunities that presented in this mixed terrain. Even near-perfect levels of RSTA and C2 could not overcome the combination of long weapon flyout times and short enemy exposure opportunities. Some additional contributions could be obtained by targeting stationary high-value targets, such as C2 centers and resupply areas, but these were not modeled in this analysis.

Ground forces with organic direct and indirect fire weapons were more responsive and selective in their fires. In combination with long-range standoff weapons, they were able to decisively defeat the enemy force. Overall, it appears that a combined fires and maneuver attack against the enemy had much greater effect than fires alone. The enemy commander would face a multifaceted threat from this approach. Of course, this comes at a cost. Some of the agile maneuver vehicles were lost to enemy fires, and the insertion itself may be extremely difficult.

We were also surprised to find that improved RSTA and C2 were far more important to ground force operations than for standoff attack, the opposite of what one might expect. Comprehensive, up-to-date intelligence and RSTA were perceived as a requisite for the insertion, setting up the ambush, targeting local indirect fires to isolate the ambush, and disengaging and

egressing from the area. Much less information was necessary to target large-footprint standoff weapons, although it appears that knowledge of the target set composition, speed, and surrounding cover would have led to more efficient use of standoff weapons.

A key decision is how much of the fight should be assigned to the different weapon systems. The long-range fires were effective only in open areas against sizable units. The ground force organic indirect fire units were lethal, but they had limited resupply. The direct fire systems were selective, but they open themselves up to return fire if gaps are not provided by the other weapons.

We noted that some tradeoffs are possible between strategic and operational mobility capabilities. If large amounts of strategic lift are available, the force can be emplaced quickly, often prior to enemy movement into the contested area. Operational mobility is then less necessary. On the other hand, operational mobility using intra-threater airlift or fast ground maneuver may be essential if the force comes in late and must penetrate deep. And, as the need for quick response increases and the strategic lift availability decreases, the importance of lightening the force becomes paramount.

In this scenario, we found that the characteristics of the long-range standoff weapons, and not the RSTA or C2 systems, were the limiting factor. On the next chart, we describe some improvements that may reduce this problem.

Insights from Research (2 of 2)
(RAND Scenario)

- **Responsiveness of fires is critical when enemy can move between cover**
  - **Short-timeline direct and indirect fire weapons (organic)**
  - **Loitering weapons**
  - **Standoff weapons with update-in-flight**
- **Foliage penetration can be critical for both sensors and weapons**
- **New measures of effectiveness such as disruption and shock are needed to complement traditional attrition measures**

Improvements in weapon responsiveness and efficiency are possible by upgrading several of the currently envisioned weapon systems. Standoff systems would benefit by adding loitering capabilities or incorporating targeting updates-in-flight. If greater responsiveness is not delivered through these means, additional information about target mix and cover would aid in the efficient application of standoff munitions. The ground force organic weapon systems, whether direct or indirect fire, are aided by greater cross-battlefield mobility, shorter flight times, and increased protection levels. All of the systems benefit from faster communications and command and control.

A very difficult problem is that of attacking targets in foliage. Even if foliage-penetrating radar can spot the targets, it may not be enough to wait for the targets to emerge into the open and attack them. It may be necessary to develop munition seekers that can track through foliage, along with warheads that can avoid fuzing on the leaves and branches, penetrate the canopy, and kill the target.

Killing combat vehicles rapidly, however, may not be enough for success. Certain key systems in the enemy rear, such as resupply units, command and control vehicles, and fire support elements, may be more critical targets than combat vehicles in the lead units. New MOEs are needed to capture the effects of shock, disruption, and delay caused by these losses.

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